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REVIEW OF MANNED SUBMERSIBLE DESIGN, OPERATIONS, SAFETY AND INS--ETC(U)
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1 OF 3
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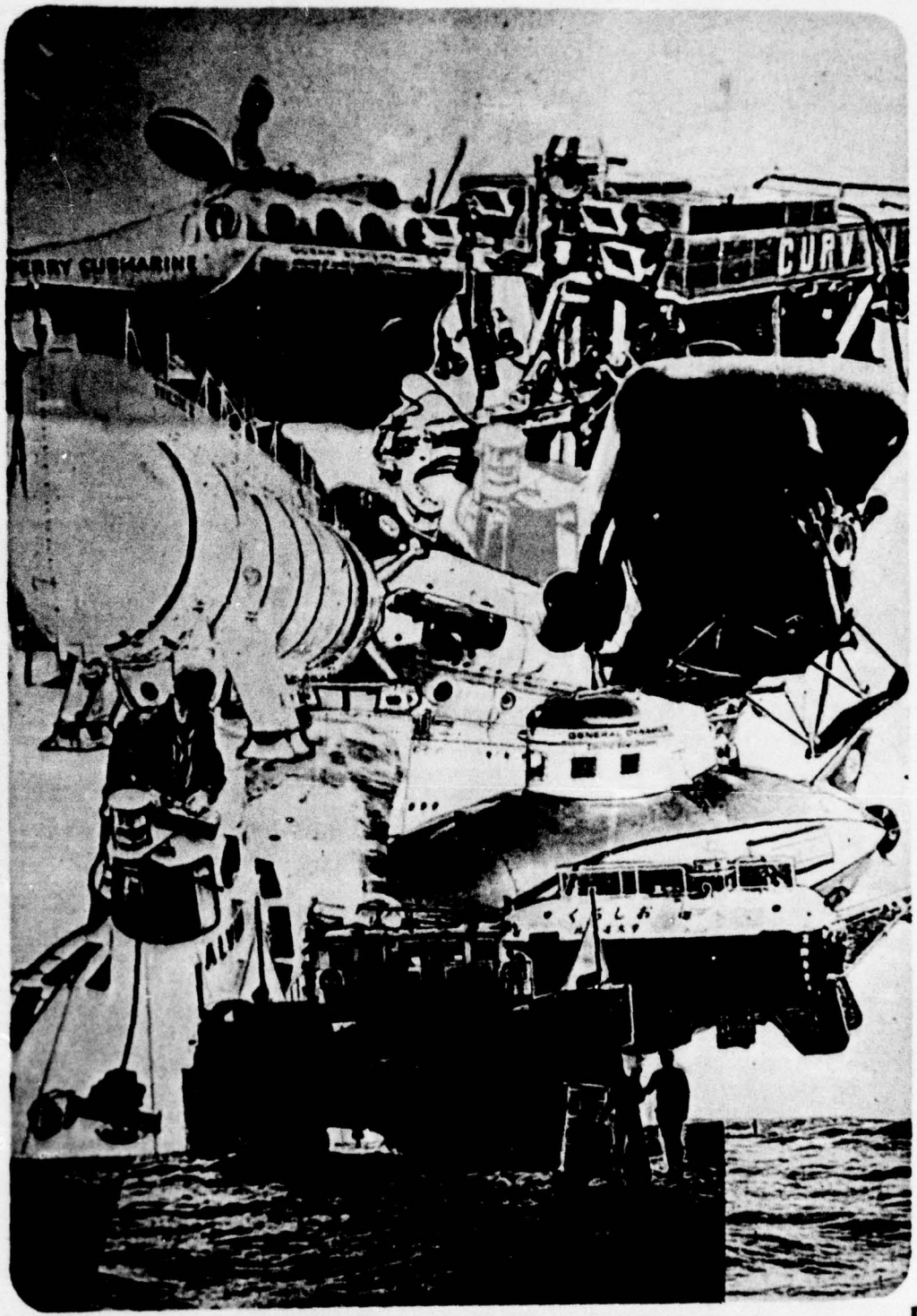
REVIEW of MANNED submersibles

design, operations, safety&INSTRUMENTATION



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CONDUCTED BY: R. FRANK BUSBY ASSOCIATES, ARLINGTON, VA.
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30 SEPTEMBER 1976

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1. A review of manned and unmanned submersibles, presently operating worldwide, was recently completed for the Oceanographer of the Navy. The review emphasized those characteristics of the various submersibles which would be of high interest in rescue situations. In most instances, data were obtained by personal observation of the submersibles and discussions with the owners and operators.

2. The data were analyzed to obtain a complete description of the vehicle in terms of dimensions, life support and emergency instrumentation. Further analyses were made to define methods of support, deployment and navigation. International search/retrieval assets were assessed and a general overview of worldwide submersible activity was obtained.

3. Enclosure (1) is a report of this endeavor and is forwarded for your retention and utilization.

R. F. Falkenstein

R. F. FALKENSTEIN
Chief of Staff
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REVIEW OF MANNED SUBMERSIBLE

DESIGN, OPERATIONS, SAFETY AND INSTRUMENTATION

30 September 1976

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U.S. Coast Guard, Underwater Safety Project

Conducted by: R. Frank Busby Associates, Arlington, Va.
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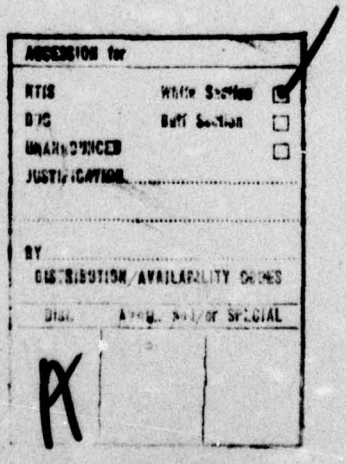

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A survey of manned and unmanned submersibles, presently operating worldwide, completed for the Oceanographer of the Navy. The review emphasizes those characteristics which would be of high interest in rescue situations. Data were obtained by personal observation of the submersibles and discussion with owners and operators.

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PREFACE

In June 1975 the U.S. Navy and U.S. Coast Guard began a 15 month study of worldwide manned submersibles. The objectives of this study were: 1) obtain a complete description of presently operating submersibles in terms of dimensions, life support and emergency instrumentation; 2) define the scope of methods used to support, deploy and navigate the various vehicles; 3) tabulate and describe the international unmanned search/retrieval assets available in the event of an emergency; and 4) obtain a general overview of worldwide submersible activities.

The impetus for this study stems from a Federal interagency agreement referred to as the National Search and Rescue Plan (SAR), wherein the Coast Guard, who is responsible for search and rescue of civilian submersibles, may request assistance from the U.S. Navy in the event of a submersible emergency. Recognizing the tremendous vehicle-to-vehicle variation in design, instrumentation and capabilities, and the unprecedented surge in submersible activities since 1973, both the Coast Guard and Navy sought to define the specific nature of these potential rescuees and formulate a practical rescue scenario. While the major submersible activities are now in the North Sea offshore oil and gas fields, the East Coast of the U.S., the Gulf of Alaska and the Arctic regions could soon become potential areas for submersible activities equal to that of the North Sea. For this reason, and to maintain a current knowledge of submersible safety/emergency procedures, this study was undertaken.

In all but a few instances, the data in this report was obtained by personally visiting and conferring with the builders and operators of the submersibles described. This effort involved traveling throughout the U.S., Canada, Japan,

Europe and the Soviet Union. Two ground rules governed the scope of this study: 1) only active submersibles and those under construction with operating depths of at least 1,000 feet (305m) were investigated; 2) no government-classified or company-proprietary data was solicited.

Not all attempts to obtain data on individual submersibles and unmanned vehicles were successful. In two instances a flat refusal to grant an interview or to answer correspondence was encountered. In another instance correspondence was unanswered. But, other than these cases, the response and cooperation by the submersible community was superb and served as a practical demonstration of the community's sincere desire to participate in any program that might contribute to the safety of their diving personnel.

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1.0 SUMMARY

1.1 GENERAL

There are 56 international manned submersibles now in operation or undergoing sea trials. An additional 22 are being refitted or constructed which will be operational by mid-1977 (Table 1.1). The focus of virtually all industrial activity is in European waters, particularly the North Sea. Industrial submersible operations in U.S. waters are negligible compared to Europe. The most active U.S. operators are the military and the academic community.

All major industrial or academic submersible builders and users comply with one of the following submersible classifying activities: American Bureau of Shipping, Lloyds Register, Germanischer Lloyds, Japan Ministry of Transport. Military submersible builders design and construct their vehicles in accordance with their own certification criteria.

Operators are unaware of national or international laws governing the construction or operations of manned submersibles other than minimal U.S. Coast Guard requirements for U.S. submersibles and Canadian Ministry of Transport regulations covering the AUGUSTE PICCARD.

Two deaths occurred in September 1975 which were submersible-related.

The major employer of industrial submersibles is the offshore oil and gas community. Submersible work is primarily concerned with visual inspection and photographic/television documentation of pipelines and hardware and of candidate sites and routes for installation of such equipment. Other industrial tasks

TABLE 1.1 MANNED SUBMERSIBLE SUMMARY

	TOTAL VEHICLES	TOTAL OPERATIONAL/ SEA TRIALS	TOTAL INACTIVE[1]	TOTAL UNDER CONSTR.	TOTAL REFIT	TOTAL STANDBY[2]
USA	28	21	4	2	1	0
CANADA	10	5	0	4	1	0
FRANCE	22	11	4	5[3]	2	0
ITALY	2	1	0	0	1	0
JAPAN	3	2	0	0	0	1
NETHERLANDS	1	1	0	0	0	0
SWEDEN	1	0	0	1	0	0
TAIWAN	1	1	0	0	0	0
UNITED KINGDOM	10	7	0	2	1	0
USSR	8	7	1	0	0	0
	86	56	9	14	6	1

1. Inactive: Has not operated since at least January 1975. Includes "unknowns."

2. Standby: Diving condition, but funding to dive unavailable.

3. Two vehicles are under construction for a French firm, but the owner does not wish to announce their capabilities at this time (July 1976).

involve a wide variety of location, retrieval and simple repair tasks. Present submersible design and instrument developments are aimed at deeper, more specialized and more complex support of the offshore oil/gas customer.

The design of submersibles continues to be non-uniform and their equipments non-standard. Modifications to the vehicles are frequent and, consequently, descriptions of individual vehicles must be confirmed frequently and with the operator for accuracy. The location (i.e., home port) of individual vehicles depends upon the location of the job. It is not unusual for submersibles to operate off one country in one month and another country several thousand miles distant the following month. The dynamics of this industry, therefore, create great difficulties in deriving a typical rescue scenario or recommendations for standard emergency equipments/procedures.

1.2 OPERATIONAL PROCEDURES

1.2.1 Launch/Retrieval

The stern-mounted A-frame is the most widely used launch/retrieval configuration for rough water conditions today. Vickers Oceanics Ltd. states that operations can be conducted up to - and including - Sea State 6; the remaining operators place the limit into Sea State 5.

1.2.2 Navigation (Submerged)

The most widely-applied, contemporary submerged navigation systems for commercial work are those utilizing a bottom-mounted transponder network. Submersible position accuracy, relative to a minimum three-transponder net, is advertised as $\pm$3 feet (0.9m).

1.2.3 Life Support Duration

Life support duration ranges from approximately 14 hours/occupant (a fully loaded DSRV) to 305 hours/occupant (AUGUSTE PICCARD). The overall average duration is 85 hours/occupant; for North Sea operations it is 112 hours/occupant. Emergency food and water is carried by 85 percent of all vehicles; emergency clothing is carried by 23 percent.

1.3 SEARCH/LOCATION (SURFACE)

Six methods are used to locate submersibles on the surface: 1) by visually sighting either the sail or conning tower; 2) by visually sighting of flashing lights; 3) by detecting and obtaining a bearing on a radio signal (beacon) or interrogating a radio transponder; 4) radar reflection off the sail or a radar target; 5) by detecting and homing on a keel-mounted pinger (underwater telephone transducer) and 6) by visual sighting of pyrotechnics released by the submersible pilot.

1.3.1 Visual Sighting

All but three submersibles have a sail or conning tower. Under ideal conditions these scantlings can be seen out to an average 5.1 nautical miles (9.5 km) from a height of 20 feet (6m). Eight vehicles have white colored sails. These are difficult to detect in the presence of white caps.

1.3.2 Surface Lights

Sixty two (62) percent carry flashing lights ranging in duration from 12 to 168 hours. The flash rate varies from vehicle-to-vehicle.

1.3.3 Radio Beacons

All but one vehicle carrys a radio transceiver; seven vehicles carry two. The range is estimated from 3 to 25 nautical miles (6 - 46 km). Fifteen vehicles carry radio beacons. Frequencies range from 2 to 243 mHz. Operating duration is from 12 to 120 hours. Two vehicles carry radio transponders.

1.3.4 Radar Reflectors

Nine vehicles are equipped with radar reflectors. The height above the water is from 2 to 6.5 feet (0.6 to 2m).

1.3.5 Surface Pingers

Less than 10 percent of all vehicles have a keel-mounted transducer or pinger.

1.3.6 Pyrotechnics

Rockets or flares are carried by 16 submersibles. All but one store their pyrotechnics in the pressure hull. All, but two, vehicles must open the hatch to activate the rocket or flare.

The best assurance the submersible has that it will be located when it surfaces is an accurate submerged tracking system aboard the support craft. Surfacing at night in Sea State 3 or greater would present a difficult, if not impossible, location problem for the majority of operators.

1.4 SEARCH/LOCATION (SUBMERGED)

Four major capabilities are available to the potential rescuer for locating a submersible that cannot surface: 1) surface location of an emergency marker buoy released by the submerged vehicle; 2) towed unmanned vehicles; 3) tethered, self-propelled, unmanned vehicles and 4) other manned submersibles.

In view of the average 3.5 days/crew member life support duration, the primary factor governing the success of these capabilities to provide timely assistance is the accuracy of the stricken vehicle's last known position. If the support ship cannot provide a location within ±1 nautical mile (1.8 km), then the search/location effort could take up a major portion of the life support available; when mobilization and transit time for the rescuer to reach the emergency scene is also subtracted, there is precious little time remaining to affect retrieval.

1.4.1 Marker Buoys

Fifty three (53) percent of all submersibles have the capability for releasing an emergency marker buoy. The marker buoy, in all but two instances, is uninstrumented and can be only visually located. Consequently, the liklihood of locating the uninstrumented buoys at night is exceptionally small. Most buoys are small in size and visually locating them in daylight hours in greater than Sea State 2 would be difficult. If currents of 1 knot (1.8 km/hr) or greater were running, it is speculative whether or not the positive buoyancy of most submersible buoys would allow them to remain afloat after they surfaced. The JOHNSON-SEA-LINK released a 20 inch (51cm) diameter sphere from 1,000 feet (305m) depth in the approximate core of the Gulf Stream. The surface current was estimated at 3 to 4 knots (6 to 8 km/hr). The buoy was tethered by a 0.2 in. (0.5cm) diameter line. The buoy surfaced and was soon dragged under by the current. This size buoy has a positive buoyancy of approximately 155 lbs (70kg). It was replaced with a 24 inch (61cm) diameter buoy. Tidally induced (periodic) currents of this magnitude can be found in many areas where submersibles now operate.

1.4.2 Towed, Unmanned Vehicles

Ten devices which rely upon a surface ship for propulsion and provide a real-time (TV) viewing capability have been identified. Two of these can reach the operational depth of any presently operating submersible. Combining real-time viewing with long range acoustic search capability, these devices provide an excellent means of location and identification of a submersible. Present towed devices, however, are limited in providing assistance within the average life support duration of submersibles; the limitations are: availability of suitably equipped support ships, and long mobilization time.

1.4.3 Self-propelled, Unmanned Vehicles

Thirty six (36) self-propelled, tethered vehicles have been identified as operating or under construction throughout the world. The greatest operating depth at present is 10,000 feet (3,048m); the average operating depth is approximately 4,000 feet (1,219m). All have TV, all provide excellent maneuvering capability and 50 percent provide a manipulative capability. The U.S. Navy's DEEP DRONE is maintained in constant readiness to perform military tasks and would assist in industrial submersible search/location.

The majority (75%) of these vehicles do not have a passive or active acoustic system by which they can home into visual (TV) range of a stricken submersible. Currents can create severe drag on the umbilical cable and thereby restrict these vehicles to limited searching range. The position, therefore, of the stricken vehicle must be precisely known if these vehicles are to realize their full search/location potential.

1.4.4 Manned Submersibles

The number of submersibles capable of coming to the aid of another submersible is first a function of depth. An examination of Table 3.1 (p. 36) clearly reveals that the shallow diving submersibles (assuming they are not beyond crush depth) have a far larger inventory of potential locators than do their deep-diving counterparts. TRIESTE II (now that ARCHIMEDE is inactive) can be reached by no submersible. ALVIN, in view of TRIESTE II's extensive mobilization and transit time, is in the same situation. This does not mean that both vehicles are beyond inspection range. The towed vehicles can reach either vehicle's operating depth, but they have no means of physically aiding either vehicle.

While there is no legal requirement to do so, it is a general practice within the submersible community for an operator to ascertain the operational status and whereabouts of other submersibles - even though they may be competitors - so that some capability is available to assist in the event of an emergency.

Underwater visibility range, in the absence of ambient light and using artificial light, is rarely more than 30 to 40 feet (9 to 12m) using either a low light level TV or the human eye. Consequently, the searcher must have a means whereby he can direct his vehicle to within this range; this means is generally, if not always, by active or passive acoustic devices. Active acoustic devices are scanning sonars, CTFM sonars or conventional forward-oriented echo sounders. Eighty two (82) percent of the vehicles listed in Table 5.1 (p.192) carry some form of active sonar which could be used to search/locate. The greatest usable range of these is 4,500 feet (1,372m).

Passive devices, those which can acquire an acoustic impulse and "home" to their source, consist of directional antenna (linear hydrophone array) and any of the CTFM or scanning sonars. The latter two devices are essentially limited to receiving a narrow band of frequencies. Thirty percent or 22 submersibles carry a form of directional antenna. There is no standard receiving frequency; some receive between a range (25 to 40; 20 to 54 kHz), others receive two frequencies (10 and 27 kHz), while others receive only one frequency (27 or 50 kHz).

All submersibles carry an active acoustic source which can be used as a source to aid in its location. The most basic and universal of these devices are underwater telephones, which are on all operating submersibles and are planned for installation on all vehicles under construction. Other active acoustic devices are CTFM and scanning sonars (which have been discussed), pingers and transponders.

Underwater telephone frequencies vary, but 8 to 10 kHz is used by 80 percent of the current operators.

Pingers of various frequencies, repetition rate, and operating duration are carried by 65 percent of present submersibles. Frequency ranges are from 8 to 45 kHz. Approximately half of those in use transmit between 27 to 37 kHz.

Transponders are carried by 25 percent of the current vehicles. There are no two submersibles that use the same interrogate-respond frequency, except in instances where a company owns and operates more than one vehicle (e.g., Vickers Oceanics, Ltd.)

Under this "self-help" category, CTFM or scanning sonars can also be included, for the submersible in extremis might acquire its searcher by the use of these instruments and "con" it to its location.

1.5 RETRIEVAL (LIFT POINTS)

There is only one general statement that summarizes the configuration, location and accessibility of lift point attachments whereby a line can be attached to lift any of the current submersibles to the surface: they all vary. The only exceptions to this statement are where more than one vehicle is operated by the same company. Further complexity towards retrieval is introduced by vehicles which have no single lift point. In essence, each potential retrieval situation must be approached on a vehicle-to-vehicle basis, and no one retrieval hook configuration can be applied to all submersibles.

The means of attaching a retrieving line is afforded by one of three means: unmanned, self-propelled vehicles; manned submersibles, and ambient-pressure divers.

Approximately 50 percent of the 36 operating and planned unmanned vehicles have some type of manipulative capability by which a line and hook can be attached. The deepest of those now operating is CURV III which can reach 10,000 feet (3,048m) in an emergency.

Approximately 80 percent of all submersibles have at least one manipulator; almost half of these have two. ALVIN, the deepest diving submersible which can realistically respond within the average life support duration of operating submersibles, can dive to - and beyond - the crush depth of any present submersible.

The greatest at-sea depth reached by an ambient pressure working diver, to date, is 1,015 feet (309m). Most commercial diving companies are working at maximum depths between 600 and 700 feet (183 and 213m) and average depths of 300 to 400 feet (91 to 122m). The mobilization time for most deep diving systems is 24 to 48 hours. Currents up to 3 knots (5.6 km/hr) are considered the operating maximum. Sea State 6 is the approximate limit of operations, and at least a 2-point moor is required to station-keep. Mobilization time is from 24 to 48 hours. An additional time-consuming factor, relative to the manned and unmanned submersible, is involved in setting up the 2 to 4-point moor necessary to hold position. If the support ship is not moored directly over the submersible, additional time is required to adjust or, perhaps, completely relocate the moor. The diver's searching capability is limited to the water clarity unless hand-held active or passive sonars are made available; these are not standard diving system equipments. In view of the extensive application of ambient divers in offshore work, it is probable that, at any given time, this capability would be ready to respond more quickly than the manned or unmanned systems. The Harbor Branch Foundation, Ft. Pierce, Florida maintains a lockout submersible (JOHNSON-SEA-LINK I or II) in an operational (ready-to-go) condition at all times; no mooring is required to employ this system. The capabilities supplied by the lockout vehicle and diver appears ideal for rapid search/location/retrieval. The U.S. Navy maintains diving systems aboard the ASR's PIGEON and ORTELONE, one on the east coast and one on the west coast. These are in addition to numerous other readily-mobilized capabilities of lesser depth.

The greatest utilizer of manned submersibles is the offshore oil and gas industry. This industry has yearly progressed its drilling activities into deeper and

deeper waters. As long as it remains profitable - and there is no present indication of this changing - drilling operations will progressively go deeper. Consequently, submersible utilization must certainly increase, not only in established offshore operations, but in new areas such as the east coast of the U.S. and the Gulf of Alaska. As more manned submersibles are employed, at increasingly greater depths, and in more hostile waters, the potential for accidents will increase accordingly.

2.0 SUBMERSIBLE ACTIVITIES - WORLDWIDE OVERVIEW

Since 1973 the utilization of manned submersibles has mushroomed. More vehicles are now operating and under construction than at any other time. Where the customer of the 1960s was the Federal Government, it is now private industry; in particular, offshore oil and gas. A listing of worldwide submersibles is presented in Table 2.1.

The classifications used in this table are defined as follows:

Operational: The submersible has operated within the period Jan. 1975 - June 1976, and submersibles that can be ready within 48 hours to dive which have a trained, operational crew available.

Sea Trials: Submersibles that have recently been constructed or refitted and are conducting test and evaluation, and/or crew training dives. The DSRV 1 & 2 are included in this category, however, the U.S. Navy defines the vehicles as being in an operational/evaluation status.

Refit: This term includes vehicles which are undergoing or will undergo major modifications to the pressure hull, propulsion plant or overall operating capabilities.

Construction: Vehicles being constructed.

Inactive: Vehicles which have not dived since January 1975.

There are several aspects of Table 2.1 which should be noted. The French firm, GO International, Marseille is rumored to have added the SP-350 and/or the two SP-500s (SEA FLEAS) to their inventory, but the firm did not respond to repeated

TABLE 2.1 CONTEMPORARY MANNED SUBMERSIBLES

NAME	DEPTH (ft/m)	BUILDER	OPERATOR	STATUS
CANADA				
AQUARIUS I	1,100/335	Hyco Vancouver, B.C.	Hyco Subsea Vancouver, B.C.	Operational
AUGUSTE PICCARD	2,000/610	Giovanola Bros. Monthe, Switz.	Horton Maritime Explorations Vancouver, B.C.	Sea Trials
PISCES IV	6,600/2,012	Hyco Vancouver, B.C.	Dept. of Environment Victoria, B.C.	Operational
PISCES V	6,600/2,012	Hyco Vancouver, B.C.	Vickers Oceanics Leith, Scotland	Operational
PISCES VI	6,600/2,012	Hyco Vancouver, B.C.	Hyco Subsea Vancouver, B.C.	Operational
SDL-1*	2,000/610	Hyco Vancouver, B.C.	Canadian Armed Forces Shearwater, N.S.	Operational
SEA OTTER	1,500/457	Anautics, Inc. San Diego, Ca.	Can-Dive Services, Ltd. Vancouver, B.C.	Operational
TAURUS*	2,000/610	Hyco Vancouver, B.C.	Hyco Subsea Vancouver, B.C.	Construction
FRANCE				
ARCHIMEDE	36,000/10,973	French Navy Toulon	French Navy Toulon	Inactive
CYANA	9,843/3,000	CEMA Marseilles	CNEXO Toulon	Operational
DEEPSTAR 2000	2,000/610	Westinghouse Elec. Annapolis, Md.	GO International Marseilles	Refit
DEEPSTAR 4000	4,000/1,219	Westinghouse Elec. Annapolis, Md.	COMEX Marseilles	Refit
GLOBULE	656/200	COMEX Marseilles	COMEX Marseilles	Operational
GRIFFON	1,969/600	French Navy & Constr. Yard Brest	French Navy Toulon	Operational

TABLE 2.1 CONTEMPORARY MANNED SUBMERSIBLES (Continued)

NAME	DEPTH (ft/m)	BUILDER	OPERATOR	STATUS
FRANCE (Cont.)				
MOANA I	1,312/400	COMEX Marseilles	COMEX Marseilles	Operational
MOANA III, IV, V				Construction
PC-8B	800/244	Perry Sub. Bldrs. Riviera Beach, Fla.	Intersub Marseilles	Operational
PC-1201	1,000/305	Perry Sub. Bldrs. Riviera Beach, Fla.	Intersub Marseilles	Operational
PC-1202*	1,000/305	Perry Sub. Bldrs. Riviera Beach, Fla.	Intersub Marseilles	Operational
PC-1203	1,000/305	Perry Sub. Bldrs. Riviera Beach, Fla.	COMEX Marseilles	Operational
PC-1204	1,000/305	Perry Sub. Bldrs. Riviera Beach, Fla.	Intersub Marseilles	Operational
PC-16*	3,000/914	Perry Sub. Bldrs. Riviera Beach, Fla.	Intersub Marseilles	Operational
PC-18*	3,000/914	Perry Sub. Bldrs. Riviera Beach, Fla.	Intersub Marseilles	Construction
SHELF DIVER	800/244	Perry Sub. Bldrs. Riviera Beach, Fla.	French Navy Toulon	Operational
SP-350	1,148/350	OFRS Marseilles		Unknown
SP-500	1,640/500	Sud Aviation		Unknown
ITALY				
PC5-C	1,200/366	Perry Sub. Bldrs. Riviera Beach, Fla.	Sub Sea Oil Services Milan	Refit
PS-2	1,025/312	Perry Sub. Bldrs. Riviera Beach, Fla.	Sub Sea Oil Services Milan	Operational
TOURS 66	984/300	Maschinenbau Gabler GmbH Lubeck, West Germany	Sarda Estracione Lavorazione Cagliari, Sardinia	Inactive

TABLE 2.1 CONTEMPORARY MANNED SUBMERSIBLES (Continued)

NAME	DEPTH (ft/m)	BUILDER	OPERATOR	STATUS
JAPAN				
HAKUYO	984/300	Kawasaki Heavy Ind. Kobe	Ocean Systems Japan Tokyo	Operational
SHINKAI	1,969/600	Kawasaki Heavy Ind. Kobe	Japan Maritime Safety Agency Tokyo	Operational
UZUSHIO**	656/200	Nippon Kokan K.K. Tokyo	Fuyo Ocean Development Co. Tokyo	Inactive
NETHERLANDS				
SKADOC 1000*	1,000/330	Skadoc Submersible Sys. Yerseke	Skadoc Submersible Sys. Yerseke	Operational
REPUBLIC OF CHINA				
BURKHOLDER I	984/300	Maschinenbau Gabler GmbH Lubeck, West Germany	Kuofeng Ocean Dev. Co. Taipei, Taiwan	Operational
SWEDEN				
URF	1,509/460	Kockums Malmo	Royal Swedish Navy	Construction
UNITED KINGDOM				
LEO	2,000/610	Hyco Vancouver, B.C.	P&O Subsea Middlesbrough	Construction
MERMAID III*	853/260	Bruker-Physik AG Karlsruhe, West Germany	P&O Subsea Middlesbrough	Operational
PC-9	1,350/411	Perry Sub. Bldrs. Riviera Beach, Fla.	P&O Subsea Middlesbrough	Operational
PC-1503*	1,500/457	Perry Sub. Bldrs. Riviera Beach, Fla.	Vickers Oceanics Ltd. Leith, Scotland	Construction

TABLE 2.1 CONTEMPORARY MANNED SUBMERSIBLES (Continued)

NAME	DEPTH (ft/m)	BUILDER	OPERATOR	STATUS
UNITED KINGDOM (Cont.)				
PC-1504*	1,500/457	Perry Sub. Bldrs. Riviera Beach, Fla.	Vickers Oceanics Ltd. Leith, Scotland	Construction
PISCES I	1,200/366	Hyco Vancouver, B.C.	Vickers Oceanics Ltd. Leith, Scotland	Refit
PISCES II	2,400/732	Hyco Vancouver, B.C.	Vickers Oceanics Ltd. Leith, Scotland	Operational
PISCES III	3,000/914	Hyco Vancouver, B.C.	Vickers Oceanics Leith, Scotland	Operational
PISCES VIII & X	3,281/1,000	Hyco Vancouver, B.C.	Vickers Oceanics, Ltd. Leith, Scotland	Operational
VOL-L1*	1,200/366	Perry Sub. Bldrs. Riviera Beach, Fla.	Vickers Oceanics, Ltd. Leith, Scotland	Operational
VOL-L2*	1,200/366	Vickers Oceanics Ltd. Leith, Scotland	Vickers Oceanics, Ltd. Leith, Scotland	Operational
UNITED STATES				
ALVIN	12,000/3,658	Litton Ind. Minneapolis, Minn.	WHOI Woods Hole, Ma.	Operational
ARMS**	3,000/914	Oceaneering Int. Houston, Tx.	Oceaneering Int. Houston, Tx.	Construction
BEAVER*	2,700/823	North American Rockwell Seal Beach, Ca.	Int. Underwater Contr. City Island, N.Y.	Refit
DEEP QUEST	8,000/2,438	Lockheed Missiles & Space Sunnyvale, Ca.	Lockheed Ocn. Lab. San Diego, Ca.	Inactive
DEEP VIEW	1,500/457	NUC San Diego, Ca.	Southwest Res. Inst. San Antonio, Tx.	Operational
DIAPHUS	1,200/366	Perry Sub. Bldrs. Riviera Beach, Fla.	Texas A&M Univ. College Station, Tx.	Operational
DOWB	4,500/1,372	General Motors Santa Barbara, Ca.	Southwest Res. Inst. San Antonio, Tx.	Refit
DSRV 1 & 2	5,000/1,524	Lockheed Missiles & Space Sunnyvale, Ca.	U.S. Navy San Diego, Ca.	Tech/Op Evaluation
GUPPY**	1,000/305	Sun Shipbuilding & Dry Dock Chester, Pa.	Sun Shipbuilding & Dry Dock Chester, Pa.	Inactive

TABLE 2.1 CONTEMPORARY MANNED SUBMERSIBLES (Continued)

NAME	DEPTH (ft/m)	BUILDER	OPERATOR	STATUS
UNITED STATES (Continued)				
JOHNSON-SEA-LINK I & II*	1,000/305	Harbor Branch Foundation Ft. Pierce, Fla.	Harbor Branch Foundation Ft. Pierce, Fla.	Operational
MARGENAUT	600/183	Martines Diving Bells San Diego, Ca.	Margen International Fairfax, Va.	Unknown
MERMAID II	1,200/366	Bruker-Physik AG Karlsruhe, West Germany	Int. Underwater Contr. City Island, N.Y.	Operational
NEKTON A, B, C	1,000/305	General Oceanographics San Diego, Ca.	General Oceanographics San Diego, Ca.	Operational
NEMO	1,000/305	Naval Civil Eng. Lab. Port Hueneme, Ca.	Southwest Res. Inst. San Antonio, Tx.	Operational
NR-1	NA	General Dynamics Groton, Conn.	U.S. Navy	Operational
OPSUB**	1,000/305	Perry Sub. Bldrs. Riviera Beach, Fla.	Ocean Systems Reston, Va.	Inactive
PC-14C-2	600/183	Perry Sub. Bldrs. Riviera Beach, Fla.	Kentron, Hawaii Huntsville, Ala.	Operational
PRV-2	1,000/305	Pierce Submersibles Bayshore, N.Y.	Minisub Associates Albertson, N.Y.	Construction
SEA CLIFF	6,500/1,981	General Dynamics Groton, Conn.	U.S. Navy San Diego, Ca.	Operational
SEA EXPLORER	600/183	Sea-Line, Inc. Brier, Wa.	Sea-Line, Inc. Brier, Wa.	Operational
SEA RANGER	600/183	Verne Engineering, Inc. Fraser, Mich.	Verne Engineering, Inc. Fraser, Mich.	Operational
SNOOPER	1,000/305	Undersea Graphics, Inc. Torrance, Ca.	Undersea Graphics, Inc. Torrance, Ca.	Operational
STAR II	1,200/366	General Dynamics Groton, Conn.	Deepwater Explorations, Ltd. Honolulu, Ha.	Operational
TRIESTE II	20,000/6,096	U.S. Navy	U.S. Navy San Diego, Ca.	Operational
TURTLE	6,500/1,981	General Dynamics Groton, Conn.	U.S. Navy San Diego, Ca.	Operational

TABLE 2.1 CONTEMPORARY MANNED SUBMERSIBLES (Continued)

NAME	DEPTH (ft/m)	BUILDER	OPERATOR	STATUS
USSR				
ARGUS	1,968/600	Institute of Oceanology Moscow	Institute of Oceanology Gelundzhik	Sea Trials
ATLANTA **	328/100	Giprorybflot Inst. Leningrad	Atlantic Research Inst. of Fisheries, Kaliningrad	Operational
OSA-3	1,968/600	Giprorybflot Inst. Ministry of Fisheries	Ministry of Fisheries Moscow	Operational
PISCES VII & XI	6,600/2,012	Hyco Vancouver, B.C.	Institute of Oceanology Gelundzhik	Sea Trials
SEVER 2	6,562/2,000	Ministry of Shipping Industries of the USSR	Ministry of Fisheries Moscow	Inactive
TETIS **	656/200	Ministry of Shipping Industries of the USSR	Ministry of Fisheries Moscow	Operating
TINRO 2	1,312/400	Ministry of Shipping Industries of the USSR	Central Res. Inst. of Fish. Moscow	Operating
WEST GERMANY				
MERMAID V*	850/260	Bruker-Physik AG Karlsruhe, West Germany	Bruker-Physik AG Karlsruhe, West Germany	Construction

* Diver Lockout
** Tethered

inquiries; hence the "unknown" status. STAR 2 is listed as operational, but, since its support catamaran (LRT) was lost in September 1975, it is not certain that the submersible is actually diving. The operators of STAR 2 were not responsive to inquiries regarding their vehicle's activities. DOWB has been referred to as a Colombian-owned vehicle, however, Mr. Edward Briggs of Southwest Research Institute, where the vehicle is located, states that it is owned by a U.S. firm whose office is in Bermuda; therefore the vehicle is classed as U.S.-owned. Data on Soviet vehicles not operated by the Institute of Oceanology was obtained from personnel of that Institute; permission to confer with Ministry of Fisheries personnel was unobtainable at the time of the Soviet Union visit (Dec. 1975).

2.1 Construction

Canada and the United States are dominant in submersible construction. The major producers are International Hydrodynamics, Ltd. (Hyco) of Vancouver, B.C. and Perry Submarine Builders of Riviera Beach, Florida. The former's production units will soon reach 14; the latter 21.

Several aspects of submersible construction have changed little since the mid-sixties. Most pressure hulls are made of low carbon or the HY series of steels, and lead acid batteries are the dominant power source. The only exception is the recently-constructed VOL-LII of Vickers Slingsby Ltd. which is composed of glass reinforced plastic.

Trends can be seen in other areas. The acrylic plastic bow dome, for example, is a feature of most new vehicles. The Perry Company now includes the bow dome in all its vehicles; Hyco includes it in their recent AQUARIUS and TAURUS. Several other vehicles have been or are being modified to incorporate a bow dome (e.g.,

the MERMAID series and BEAVER). Operational depth of new submersibles is still relatively shallow (excluding the 6,500 ft (1,981m) PISCES series), but Perry's PC-16 and PC-18 are designed for 3,000 ft (914m), a two-fold depth increase over their previous vehicles.

PC-16 and PC-18, and Hyco's TAURUS are designed for dry, one-atmosphere transfer of personnel and equipment. The dry transfer feature, though not new, reflects a trend brought about by projected sub-sea completion needs of offshore oil and gas. The first of these vehicles, PC-16, successfully completed at-sea testing in May of this year. Details of the remaining dry transfer vehicles are too sparce for inclusion in Section 3.0.

An innovative trend is seen in the construction and utilization of COMEX's GLOBULE with its Cable Burial Machine. The Cable Burial Machine is a 25 ton (22.6t), underwater, caterpillar tractor which receives its power from a surface umbilical and is equipped with a steel ploughshare and a sediment jetting system. Control of the Burial Machine is accomplished by GLOBULE's two-man crew who dive to the machine, magnetically lock on to a 270 degree revolving platform and use the umbilical for power. When a day's work is completed, the crew detaches GLOBULE and returns to the surface leaving the Cable Burial Machine on the bottom.

DOWB, now at Southwest Research Institute, was scheduled for modifications that will provide capabilities similar to GLOBULE and its Burial Machine, however, these modifications had not begun when this report was published.

2.2 Operational Activity

A dive-by-dive compilation of submersible activities was not an objective of this survey; a general overview of activities within the field was.

2.2.1 Japan

Two submersibles are presently operating in Japan: SHINKAI and HAKUYO. A third tethered submersible, UZUSHIO, experienced an accident while diving in May 1974. The accident resulted in the loss of two lives and since then UZUSHIO has not dived. SHINKAI is owned by the Japan Maritime Safety Agency and has been active in biological investigations, gravity measurements, cable inspection and geological studies. HAKUYO is operated by a private company, Ocean Systems Japan, Ltd., and is active in commercial projects which include bottom surveys for pipelines and cables, bridge construction and other survey/sampling tasks involving undersea engineering.

The Japanese Marine Science and Technology Center (JAMSTEC), at Yokosuka, is pursuing a variety of tasks associated with submersible construction and capabilities. These include: development of a bilateral manipulator, underwater radio communications, development and training programs for a wet and dry hyperbaric chamber of 500 meters (1,640 ft) depth capacity and a feasibility study for a 6,000 meter (19,685 ft) submersible. In September 1975 the emphasis was shifting from the 6,000 meter submersible to a much shallower vehicle with lockout capability.

JAMSTEC was also involved in construction and utilization of the underwater habitat SEATOPIA. In 1973 SEATOPIA was used in saturation dives at 60 meters (196 ft) depth. The ultimate goal of 100 meters (328 ft) had not been reached at this time and emphasis has shifted toward developing the hyperbaric diving facility and decompression tables for use in subsequent saturation diving.

A prototype model for a Japanese Rescue Vehicle has been constructed and successfully tested. The rescue vehicle, CHIHIRO, was operational to only 50 meters

(164 ft) depth, but the final version will be designed for 900 meters (2,953 ft) and accommodate 12 rescuees. Its completion is tentatively scheduled by 1979. A 1974 summary of all Japanese submersibles and a sampling of their activities is provided by Mr. H. Ishikura (see "Activities," Sect. 6.0).

2.2.2 Republic of China

Only one submersible is reported operating in the Republic of China, BURKHOLDER I, a 300 meter (984 ft) depth vehicle owned and operated by Kuofeng Ocean Development Corp., Taipei, Taiwan. BURKHOLDER I's activities have been in the collection of gem-quality coral in the offshore areas of Taiwan.

2.2.3 Canada

Submersible activity in Canada centers around the west coast, specifically British Columbia, where all but one of its vehicles are home-ported and most were constructed. The major exception is SDL-1 which is home-ported in Shearwater, Nova Scotia.

SEA OTTER has been engaged in cable inspections, outfall and dam inspections and other observational tasks related to hardware implantment and performance. The summer of 1975 was spent in cable inspections in the Straits of Mackinac and the summer of 1976 is seeing utilization in pipeline inspection/documentation in the Gulf of Mexico from August through October.

AUGUSTE PICCARD underwent a complete refitting and began conducting sea trials in April of 1976 which are still underway in the Vancouver area. The refitting is aimed at providing a submersible capability to conduct geophysical and gravity surveys. Being the largest submersible in the world, AUGUSTE PICCARD's operators anticipate semi-autonomous operations and ultimately, are viewing under-ice operations. Initially, the submersible will operate in the open sea. The same

firm, Horton Maritime Explorations, Ltd., owns the BEN FRANKLIN, but there are no immediate plans to place it back in operation.

Hyco's activities are mainly constructional, but in 1975 an operating arm of Hyco was formed and called Hyco Subsea, Ltd. Hyco Subsea now has three operational vehicles, PISCES V, VI and AQUARIUS I. During the period of this survey, five vehicles were completed by Hyco: PISCES VI, VII, VIII, X and XI. Design work and construction began on four more vehicles: AQUARIUS II & III, TAURUS and LEO. AQUARIUS I worked on undersea cable tasks on the east coast of the U.S. (Long Island Sound) and Canada in the summer and fall of 1975. It is now operating in the Gulf of Mexico on tasks with pipeline and associated oil/gas hardware. PISCES V is on lease to Vickers Oceanics, Ltd. and has been operating in the North Sea oil/gas field for over a year. PISCES VI was completed in February 1976 and had not undertaken any major projects as of July of the same year. The pressure hulls of AQUARIUS II and III have been completed, but further construction of the vehicles has been halted.

The Canadian Department of Environment's PISCES IV spent the period May through September in the Beaufort Sea. It was used to collect supportive data for an environmental impact assessment prior to granting drilling rights in the Beaufort Sea. The 1976 summer season was spent conducting a variety of scientific investigations for the Department of the Environment and Department of National Defense.

SDL-1, operated by the Canadian Armed Forces, has been steadily employed in classified, military tasks. In the winter of 1975 it was completely disassembled for a major overhaul which is scheduled for completion in June 1976. A new support ship for SDL-1 is undergoing overhaul and refit at Shearwater; its operational date is projected as March 1977. In support of the SDL-1's activities

the Canadian government is studying underwater emergency lockout. The goal of this study is to provide a 500 ft (152m) emergency egress system which will serve, not as a last ditch effort, but as an acceptable initial alternative.

2.2.4 United States

For convenience, U.S. submersibles will be discussed under the heading of Military, Research/Academic and Industrial.

Military - Submarine Development Group One, in San Diego, is the operator for most of the Navy's manned submersibles; they include: SEA CLIFF, TURTLE, DSRV 1 & 2 and TRIESTE II. During 1975 SEA CLIFF and TURTLE completed 114 dives off the Hawaiian Islands and in the Panama Basin doing extensive observation and photographic documentation and sampling of sea floor geological features from depths to 5,400 feet (1,646m), range maintenance duties and relocation of bottom-mounted hardware. The DSRVs are currently undergoing technical evaluation in San Diego. The evaluation program has included, to date,: system fly-away exercise; mate/demate with a support submarine; underwater transfer between DSRV and submarine; mating to a simulated distressed submarine at 2,000 feet (610m) and submerged launch/retrieval from a cable-suspended underwater platform. These activities and problems encountered in compensating fluids, cable/connectors, corrosion, batteries (silver zinc), buoyancy materials (syntactic foam) and launch/retrieval are discussed in some detail by W.E. Johnson and others (see "Activities," Sect. 6.0).

NR-1, the only nuclear-powered submersible, is based on the east coast and is operating. Virtually every other aspect of NR-1 is classified.

The Navy's NEMO and DEEP VIEW are on indefinite load to Southwest Research Institute. NEMO has not operated under contract since arriving at the Institute and DEEP VIEW has been undergoing extensive modifications, but is not yet classed as operational.

ALVIN, operated by Woods Hole Oceanographic Institution,has been operating in the Caribbean and conducted several dives in the Cayman Trough. All of ALVIN's work has been scientific and primarily in geological investigations, 57 dives were conducted in 1975. A variety of reports and papers have been issued by the ALVIN group; these are referenced in Section 6.0 and deal with: navigation, electrical cabling, battery charging procedures, gyrocompass performance, weight and stability determinations and the operation of ALVIN.

The U.S. Army's Ballistic Missile Defense Systems Command acquired the PC-14C-2 in July 1975. The PC-14C-2 replaces the PC3A-1 and 2. Both were decommissioned earlier in the year. The new vehicle is continuing the task of missile location on the Kwajalein Island missile range.

Research/Academic - Three vehicles are in this category: DIAPHUS (PC-14C) and JOHNSON-SEA-LINK I & II.

DIAPHUS belongs to Texas A&M University and by September of 1975 had conducted 140 dives since its delivery in June 1974. The submersible is used in a variety of observational/research tasks by the University which include ecological and geological studies at various locations in the northern Gulf of Mexico.

JOHNSON-SEA-LINK I & II are owned by the Harbor Branch Foundation, Ft. Pierce, Florida. JOHNSON-SEA-LINK I has been operational since 1970. JOHNSON-SEA-LINK II is virtually identical to its sister submersible and was launched in the fall of

1975. JOHNSON-SEA-LINK I has been engaged in a variety of projects; these include biological and geological studies and surveys in Florida and the Bahamas and support of diver/scientists in ecological studies. Much of the Harbor Branch Foundation's work involves development of oceanographic tools and systems for undersea research. Toward this objective JOHNSON-SEA-LINK I has assisted in pioneering the use of new diver gas mixtures and decompression tables. Research involving carbon dioxide scrubbing compounds and CO_2 scrubber systems is also being conducted at the Harbor Branch; this is referenced in Section 6.0 under "Life Support."

The Harbor Branch Foundation conducted a series of self-help, rescue exercises that, as far as is known, are the first of their kind in the manned submersible community. During the period 6 - 9 July 1976, the JOHNSON-SEA-LINK I simulated a distressed, bottomed submersible in varying depths of water some 12 to 14 nautical miles east of Ft. Pierce, Florida. Three procedures for attaching a retrieving line to JOHNSON-SEA-LINK I were evaluated: 1) by another submersible (JOHNSON-SEA-LINK II); 2) by an unmanned, self-propelled, tethered vehicle (CORD), and 3) by inflating an emergency buoy that would ascend to the surface where a retrieval hook and line could be slid down the buoy's line to engage with (and subsequently lift) the submersible. The tests were conducted initially in 125 feet (38m) of water where both the surface and sub-surface current were less than 0.1 knot (0.2 km/hr) and thence in 225 feet (69m) depth where the surface current was approximately 3 knots (5.5 km/hr) and the bottom current about 0.1 knot. In both situations all three procedures worked successfully. Visibility range in both areas was estimated at 30 feet (9m). The strong surface current presented a problem to the buoyed-line approach by tending the line at an angle of

approximately 40 degrees from the vertical which did not allow the drop-lock (see JOHNSON-SEA-LINK I or II description in Sect. 3.0) to seat itself in the lift housing. But, by taking a strain on the line from the surface, it was oriented near-vertical and the drop-lock and lift line engaged as anticipated.

Two other developments are underway at the Ft. Pierce facility which pertain to the manned submersible field: 1) design of a third observational submersible is almost completed and construction is anticipated to begin in 1977. This will be a two-sphered (plastic) vehicle with no lockout capability and 2,000 feet (610m) operational depth capability; 2) a design study, now in its third year, for a semi-submersible launch/retrieval support craft is also nearing completion. This platform is designed to support two vehicles concurrently, but no date for commencing construction is available.

Industrial - Commercial submersible activity in the U.S. offshore areas is modest. The deepest diving commercial vehicle, DEEP QUEST, has not dived since November 1973. OPSUB, which has been in Norway since 1973, has never made an operational (contracted) dive since its launching in 1972 and GUPPY has not dived for several years. The remaining vehicles have seen occasional utilization in inspection of pipelines, cables, dams, effluent outfalls and bottom investigations. The most active of these has been the NEKTON series which have conducted inspections and observations in the offshore oil and gas fields of the Gulf of Mexico. NEKTON GAMMA operated off the northeast U.S. coast for the National Oceanic and Atmospheric Administration during June through August 1976 conducting geologic, biologic and ecologic surveys and studies. MERMAID II underwent extensive modifications which were completed in May 1976, but, except for a short series of photographic dives on the ANDREA DORIA, the vehicle has not been under contract.

One of the more active submersibles was the Hawaii-based STAR II in collecting gem-quality coral. On 5 September 1975 two of STAR II's support divers were apparently drowned while freeing the vehicle from its submerged launch/retrieval platform (LRT). This has been the only submersible-related fatality since 1973. The proximate cause of this casualty, according to the Coast Guard, was loss of reserve buoyancy due to failure and collapse of Polyurethene foam installed in the LRT. The two divers, knowingly or otherwise, remained with the sinking LRT beyond a depth from which they could surface safely. Investigation of buoyant (syntactic) foam on the U.S. Navy's ALVIN, SEA CLIFF and TURTLE revealed that loss of positive buoyancy has occurred due to absorption of water; the foam is being replaced.

Oceaneering International, under an agreement with DHB Limited of England, has begun to utilize the one-atmosphere diving suit, JIM, in the commercial offshore market. As of April 1976 there were six operational JIM suits, four have been classed by Lloyds Register. A deeper, 3,000 ft (914m) version of JIM, to be called SAM, is under development and is aimed - not only at greater depths - but to provide the diver greater freedom of movement. The first commercial application of JIM was in 1974 off the Canary Islands in a depth of 375 feet (114m); since then JIM's most impressive assignment was a series of test dives off Melville Island in the Canadian Arctic where JIM-5 performed a variety of oil field type work to depths of 905 feet (276m) in 27.4 degrees F (37 degrees C) water for durations up to 5 hours 59 minutes.

A parallel effort at Oceaneering involves the development of a 3,000 ft (914m) tethered, self-powered, diving bell called ARMS (Atmospheric Roving Manipulator Systems). Similar to NEMO in many aspects of its operation and control, it is

specifically designed to provide observation and working capability on the blowout preventer (BOP) and ancillary undersea equipment of the Norwegian drillship, PACNORSE I, scheduled for delivery in April 1977. A unique feature of this system is its General Electric-developed manipulator which duplicates the movement of the operator's arm and hand inside the pressure hull and provides "feel" in the way of force feedback. A preliminary, but fairly detailed description of the ARMS and its manipulator is contained in OFFSHORE, 1976 (vol. 36, n.5).

2.2.5 Europe

Activity in offshore European waters is concentrated in the North Sea where the depths, temperature and tasks have combined to give the submersible a competitive edge over many traditional diver-performed tasks. Vickers Oceanics, Ltd. dominates the submersible market at present with six operational vehicles. In April 1974 Vickers reportedly received interim classification from Lloyd Register for their new VOL-L2 vehicle. Built by Vickers, L2 is composed of glass reinforced plastic and designed for an operational depth of 1,200 ft (366m).

Intersub Ltd., a French firm owned by Northern Offshore Ltd., is next with three operational vehicles and P&O Subsea Ltd. is last with two. All of these companies have additional vehicles on order which are reflected in Table 2.1. The Italian-based firm, Sub Sea Oil Services, S.p.A. of Milan, is also in the North Sea with one submersible, as is the Dutch firm of Skadoc Submersible Systems, Yerseke.

The French diving firm of COMEX, Marseille, has long been an active ambient diving participant in the North Sea. In January 1976 COMEX had two operational submersibles which were being used for pilot training in Marseille. Additionally, COMEX was building three more vehicles of the MOANA series, refurbishing another

and had one more on order. While COMEX's operations are worldwide, it is planned that a part of this incipient submersible fleet will see North Sea activity, particularly the MOANA vehicles which were designed specifically for North Sea conditions.

The Marseille-based firm of GO International purchased and took possession of DEEPSTAR-2000 in the fall of 1975. As mentioned in the preface, this company was unresponsive to this survey and the current status of this vehicle, or others which it may have, is unknown.

The French Navy's two submersibles, GRIFFON and SHELF DIVER, have been active pursuing military tasks off the western and southern coasts of France. ARCHIMEDE, the world's deepest diving bathyscaph, was taken off the active roles in 1974; it will remain in an inactive status unless unforeseen requirements cause its reactivation.

CNEXO's submersible CYANA was active in the summer of 1975 conducting bottom surveys for commercial oil and gas interests in the Mediterranean. CYANA underwent an overhaul in the winter of 1975-76 and was operational in the spring of 1976.

The Swedish Navy is funding the construction of URF, a submarine rescue submersible. The vehicle is being built at Kockums Shipyard in Malmo where Kockums personnel are working in conjunction with COMEX to design and instrument URF.

Other submersible construction in Europe is in Karlsruhe, West Germany, where the firm of Bruker-Physik AG is constructing the MERMAID III and IV. Both of these vehicles will have lockout capability; one is sold to P&O Subsea, the other was uncommitted as of January 1976. The West German firm Machinenbau

Gabler of Lubeck has designed a variety of small and very large submersibles, the latest being TOURS 430 which incorporates lockout capability and the ability to drill 656 feet (200m) long sediment cores, but actual construction had not begun on any submersible in early 1976.

The nature of work conducted by submersibles in the North Sea is varied, but is primarily in support of oil and gas hardware emplantment, inspection and repair. These tasks are herein categorized as Survey/Inspection and Maintenance Repair. Not all of the submersibles now operating offer the same instrument/work tool or navigational capabilities; consequently, the following tasks represent the field in general, not each vehicle specifically.

Survey/Inspection

Route and Site Surveys

- Visual and video observations and recordings of potential sites/routes.
- Acoustic and photographic mapping (side scan sonar; echo sounder, still camera) of candidate locations before and after preparation (i.e., trenching, sweeping)
- Acoustic profiling of a pipeline trench
- Rock and sediment sampling
- Removal of objects impeding hardware implantment

Hardware Implantment

- Inspection for suspended pipeline sections
- Burial of cable repeaters
- Inspection for proper installation in a trench or on a site

Maintenance/Repair

Inspect pipeline concrete coatings immediately after installation and periodically thereafter

Cathodic protection level measurements

Hooking or releasing lines, cables, buoys

Install or remove bolts and other components

Explosive cutting

Locate and retrieve lost objects

Diver lockout support - provide power for hydraulic hand tools; mobile tool kit; lighting, and an observation chamber for diver supervisor

Many of the foregoing inspection tasks are conducted prior to, during and after implantment of a cable, pipeline or structure; hence, the submersible's at-sea attendance can be required for an extended period of time. In some tasks, more than one submersible is carried aboard the support craft. Other work capabilities, such as explosive welding, non-destructive testing and personnel transportation/transfer to subsea completion systems, are being developed. One of the most active, if not the most active, in the area of developing new submersible work capabilities is Vickers Oceanics Ltd. Vickers has also developed a submarine personnel rescue capability by adding a bell-shaped mating skirt to its VOL-L1. During a one weekend trial period in early 1976, VOL-L1 made ten two-way trips to the Canadian Submarine HMSC OJIBWA where mating and personnel transfer were successful on each trip.

The quantity of hardware on the North Sea floor is growing rapidly and by orders of magnitude. It is reported that by 1980, over 1,500 miles (2,780 km) of pipeline will be in the British sector alone; some of this will be in 400 ft (122m)

of water and individual sections will be over 200 miles (371 km) long. It would appear that future submersible activity in this area will be substantial.

2.2.6 USSR

Submersible operations in the Soviet Union are conducted by the Ministry of Fisheries and the Institute of Oceanology. The Ministry of Fisheries' activities are directed towards biological studies, assays of foodstocks and evaluation of fishing techniques; they have several vehicles, of which OSA-3 is the latest. The Institute of Oceanology is presently developing its submersible capability and is conducting familiarization/training dives with the PISCES VII and ARGUS in the Black Sea. A third vehicle, PISCES XI was delivered to the Soviets in April 1976. It is scheduled for deep dive trials in the North Pacific in the fall of this year. Additional undersea efforts by the Institute of Oceanology are in the areas of saturated diving and design/construction of unmanned, self-propelled vehicles. A 984 ft (300m) wet and dry chamber, hyperbaric facility is under construction at Gelundzhik (the Institute of Oceanology's Crimean field base), as is the unmanned, self-propelled MANTA 1.5. Personnel at the Institute of Oceanology report that in 1974 the submersible GVIDON was lost in 656 feet (200m) of water, but with no loss of life.

3.0 SUBMERSIBLE CHARACTERISTICS

The following pages contain dimensional, instrumentation and operational descriptions of submersibles now operating or under construction. For quick reference to submersibles of varying operational depths, Table 3.1 is included.

The questionnaire in Appendix I lists the information sought for each vehicle. If the equipment listed in Appendix I is not mentioned in the description, it is not on the vehicle.

In some instances, the descriptions are not as complete as in others; the reasons being that the vehicle was either under construction or newly acquired and the operator did not know at the time what direction he would take toward operational/emergency instrumentation or procedures. In other instances, entire descriptions are missing, e.g., PISCES I, VOL-L2, STAR II. In these cases, for example, the vehicle was undergoing complete refit (PISCES I), or the data was company proprietary (VOL-L2), or the operator simply did not respond (STAR II). All weights in the descriptions are dry weights (in air) unless otherwise stated. If the submersible was built to metric system units, metric units are presented first and their English equivalents given in parentheses and vice versa if the vehicle was built to English units.

A note of caution must be given regarding the currency of the following descriptions. All operating submersibles may undergo modifications aimed at increasing their capabilities at any time; therefore, a description of a particular vehicle which may have been thoroughly accurate in January of 1976, may be rendered inaccurate by June of the same year. The recent history of International Underwater Contractor's (IUC) MERMAID is an excellent example of the dynamics of the submersible field.

TABLE 3.1

MANNED SUBMERSIBLES IN ORDER
OF INCREASING OPERATING DEPTH

	Feet/Meters		Feet/Meters
MARGENAUT	600/183	MOANA III	1312/400
PC-14C-2	600/183	MOANA IV	1312/400
SEA EXPLORER	600/183	MOANA V	1312/400
SEA RANGER	600/183	PC-9	1350/411
GLOBULE	656/200	DEEP VIEW	1500/457
UZUSHIO	656/200	PC-1503	1500/457
PC-8B	800/244	PC-1504	1500/457
SHELF DIVER	800/244	SEA OTTER	1500/457
MERMAID III	853/260	URF	1509/460
BURKHOLDER I	984/300	SP-500	1640/500
HAKUYO	984/300	GRIFFON	1969/600
TOURS 66	984/300	SHINKAI	1969/600
GUPPY	1000/305	AUGUSTE PICCARD	2000/610
JOHNSON-SEA-LINK I	1000/305	DEEPSTAR 2000	2000/610
JOHNSON-SEA-LINK II	1000/305	LEO	2000/610
NEKTON A	1000/305	SDL-1	2000/610
NEKTON B	1000/305	TAURUS	2000/610
NEKTON C	1000/305	PISCES II	2400/732
NEMO	1000/305	*BEAVER	2700/823
OPSUB	1000/305	ARMS	3000/914
PC-1201	1000/305	PC-16	3000/914
PC-1202	1000/305	PC-18	3000/914
PC-1203	1000/305	PISCES III	3000/914
PC-1204	1000/305	PISCES VIII	3281/1000
PRV-2	1000/305	PISCES X	3281/1000
SKADOC 1000	1000/305	DEEPSTAR 4000	4000/1219
SNOOPER	1000/305	DOWB	4500/1372
PS-2	1025/312	DSRV 1	5000/1524
AQUARIUS I	1100/335	DSRV 2	5000/1524
SP-350	1148/350	SEA CLIFF	6500/1981
DIAPHUS	1200/366	TURTLE	6500/1981
MERMAID II	1200/366	PISCES IV	6600/2012
PC5-C	1200/366	PISCES V	6600/2012
PISCES I	1200/366	PISCES VI	6600/2012
STAR II	1200/366	DEEP QUEST	8000/2438
VOL-L1	1200/366	CYANA	9843/3000
VOL-L2	1200/366	ALVIN	12000/3658
MOANA I	1312/400	TRIESTE II	20000/6096

* See Addendum

In early 1975 MERMAID II (which had been called MERMAID I/II) was purchased by IUC from Bruker Physik AG and underwent immediate modifications. These included:

- -Installation of a plastic bow dome;
- -Installation of new electric and hydraulic hull penetrators to increase external equipment capabilities;
- -Battery power was increased from 15.8 kWh to 18.5 kWh;
- -Two steel variable ballast tanks were replaced by four fiberglass tanks of larger capacity;
- -Upper and lower bumpers were added for protection.

At this point (July 1975), IUC was visited and a description of the vehicle was written. In August the submersible was hired as a photographic platform to film a production dealing with the sunken ANDREA DORIA some 200 nautical miles (371 km) off the U.S. east coast in 240 feet (73m) of water. The ANDREA DORIA dives revealed a number of shortcomings in MERMAID II's capabilities, and another series of modifications followed which were completed in the spring of 1976. These included:

- -A 180 degree port/starboard training capability to the main thruster;
- -Relocation of the bow thruster from amidships to the bow;
- -Addition of a 5 degrees-of-freedom manipulator;
- -Installation of a ground fault detector;
- -Thruster controls were made portable;
- -A pan and tilt mechanism was added;
- -The emergency buoy system was redesigned;
- -An obstacle avoidance sonar, underwater television camera with monitor/recorder and thallium iodide lights were added.

Fortunately, these modifications were made available by IUC in time to change the original description. They are discussed above, however, to demonstrate the fragile, time-dependent nature of any submersible description, and the need for near-constant monitoring of each vehicle if it is to be described accurately.

ALVIN

CHARACTERISTICS

Length	23 ft (7m)
Beam	8.5 ft (2.6m)
Height	13.1 ft (3.9m)
Draft	7.6 ft (2.3m)
Weight (dry)	16.1 tons (14.6t)
Operating Depth	12,000 ft (3,658m)
Collapse Depth	25,000 ft (7,620m)
Launch Date	1964
Hatch Diameter	20 in. (50.8cm)
Life Support Duration	216 man hrs
Total Power	42.7 kWh
Speed: Cruise (kts/hrs)	1/NA
Max (kts/hrs)	2/NA
Crew: Pilot(s)	1
Observer(s)	2
Payload	1,000 lbs (453kg)
Color	White

Pressure Hull: Spherical shape, 84 in. (213cm) OD, 1.93 in. (4.9cm) thick, composed of titanium alloy.
Power Source: Lead acid batteries, pressure-compensated, provide 30 VDC, 475 amp-hrs (eight hr rate) and 60 VDC, 475 amp-hrs (eight hr rate). Emergency power inside pressure hull provided by three nickel cadmium batteries.
Maneuvering Control: Main propulsion is provided by a trainable (50 degrees p/s), stern mounted, ten hp propeller. Two thrusters, powered by a six hp hydraulic motor, are located amidships and are 360 degrees rotatable in the vertical plane.
Pitch/Trim: A total of 550 lbs (249kg) of mercury may be pumped forward or aft to provide approximately ± 17 degrees bow angle.
Life Support: Three O_2 flasks each carrying 230 SCF at 2,475 psi (174kg/cm^2), all are located inside pressure hull. CO_2 is removed by scrubbing through LiOH. Monitors for O_2, CO_2, temperature, humidity and pressure. Backup monitors for O_2, CO_2 and pressure. All properties are checked once every 30 minutes.
Viewing: Four large viewports, one views forward, two view p/s of forward looking viewport, and one looks directly downward. A small viewport is located in the hatch cover. Two, fixed, external TVs with a video recorder.
Manipulator: One, jettisonable, electrically-powered, six degrees-of-freedom, 63 in. (160cm) maximum extension, scissors type claw with special adapters, 50 lbs (23kg) lift capacity at maximum lateral extension.
Lift Points: For submerged recovery a 5/8 in. (1.6cm) steel cable loop is attached to normal lift points on sphere (inside sail) and is held in a position atop the sail.
External Lighting: Ten lights total: Three are strobe lights for photography; two are 150 w thallium iodide; five are incandescent (quartz iodide) of 350 w and 750 w power. Nine illuminate forward, one illuminates aft. Configuration and number may change according to dive tasks.
Life Jackets: Three, inflatable
Distress Rockets: Twenty-four pen-light red flares are carried inside pressure hull.
Radar Reflector: Corner reflector, collapsible, wire mesh screen carried inside sail. Height above water surface is 6.5 ft (1.9m).
Surface Lights: One, flashing white, (OAR Mod. SF500), self-powered, 12 hrs duration at standard flash rate of once every two seconds, 48 hrs duration at decreasing flash rate. Height above water surface is six ft (1.8m).
Fire Extinguisher: One, dry chemical.
Emergency Food & Water: C-rations and six to ten pts (three to five l.) of canned water.
Medical Supplies: First aid kit

Surface Communications: VHF transceiver (Modar Mod. ASA 1520 AK), six channels, 156 mHz, powered off main batteries. CB (Lafayette Dycom 12A), self-powered.
Sub-Surface Communications: One underwater telephone (Straza Mod. 504), 8.0875 kHz, one transducer topside; one on keel, operates off main and emergency power.
Surface Homing Devices: Radio beacon (OAR MOD. ST-206-12RA), transmits on 27-30 mHz, self-powered. Underwater telephone. Transducer on keel.
Sonars: CTFM scanning sonar (Ametek Straza Mod. 500), 82 to 72 kHz, scans 120 degrees p/s. Pinger, 37 kHz, pilot-activated, self-powered, 14 days duration at reduced rep. rate, normal rep. rate five pings/second. Echo Sounder, 12 kHz, CRT display, 12,000 ft (3,658m) range.
Jettisonable Components: Two ascent weights of 200 lbs (91kg) each. Three batteries weighing 580 lbs (263kg) each. After vehicle body 2,430 lbs (1,102kg). Upon separation from after body the pressure hull and sail will float to surface.
Emergency Breathing: Three closed circuit systems which draw off the normal O_2 supply and use baralyme to remove CO_2. Each occupant is provided between three to six hours duration.
Communications Procedure: Check with surface every 30 minutes, dive is aborted if no contact is made within 60 minutes.

System Readiness: Operational
Classification/Certification: U.S. Navy Certified
Support Ship: DSRVT LULU
Owner: Office of Naval Research
Operator: Woods Hole Oceanographic Institute
Woods Hole, Mass. 02543
Builder: Litton Systems
Point-of-Contact: L.A. Shumaker
(Address same as operator)
Telephone: (617) 548-1400 ext. 408
Cable: OCEANINST

AQUARIUS I

CHARACTERISTICS

Length	13.5 ft (4.2m)
Beam	6.5 ft (1.9m)
Height	6.6 ft (2.0m)
Draft	5.3 ft (1.6m)
Weight (dry)	6 tons (5.4t)
Operating Depth	1,100 ft (335m)
Collapse Depth	1,800 ft (549m)
Launch Date	1974
Hatch Diameter	18 in. (46cm)
Life Support Duration	336 man hrs
Total Power	21 kWh
Speed: Cruise (kts/hrs)	2/NA
Max (kts/hrs)	3.4/NA
Crew: Pilot(s)	1
Observer(s)	1
Payload	880 lbs (399kg)
Color	White, orange sail

Pressure Hull: Cylindrical shape with hemispherical end caps, composed of A516 steel and acrylic plastic bow dome. Total length is 8.9 ft (2.7m), 47 in. (120cm) ID.
Power Source: Lead acid batteries inside two pressure-resistant pods provide 225 amp-hr at 120 VDC and 72 amp-hr at 12 and 24 VDC. Emergency power (10 amp-hr at 12 VDC) inside pressure hull for CO_2 scrubber and surface and sub-surface communications.
Maneuvering Control: One reversible, trainable (90 degrees p/s) stern-mounted propeller provides all propulsion and maneuvering control.
Life Support: Oxygen flasks containing 200 SCF (5.7m^3) O_2 are carried inside the pressure hull. CO_2 is removed by scrubbing through LiOH. Continuous monitors for O_2, temperature, humidity and pressure. CO_2 is checked as required.
Viewing: Acrylic plastic bow dome 36 in. (91cm) diameter, four viewports girdle conning tower. External (fixed) and internal (hand-held) television with video recorder.
Manipulator: One, claw jettisonable, six degrees-of-freedom, scissors type claw with maximum opening of 7 in. (17.8cm) and grip force of 158 lbs (72kg).
Lift Point: A steel ring 6 in. (15.2cm) ID is attached to a two point nylon bridle which terminates above the conning tower. Ring lays flat during dive. Lift capacity is 6 tons (5.4t).
External Lighting: One 250 w, thallium iodide light (Hydro Products Mfg.) located on brow above bow dome.
Life Jackets: Two, inflatable
Distress Rockets: Six, red, hand-held flares carried inside the pressure hull.
Surface Lights: One, blue/white, flashing light, 3 ft (0.9m) above water surface, once/second flash rate, self-powered, 100 hours duration.
Fire Extinguisher: One, dry chemical
Emergency Food and Water: Seven pints (3.3 l.) water. Glucose and vitamin pills. Equal to seven days duration. Emersion suits carried for cold protection.
Medical Supplies: First aid kit
Surface Communications: One VHF transceiver, 5 w, 171.96 mHz.
Sub-Surface Communications: One underwater telephone (Sub Comm 200S-20), 9 and 27 kHz, may serve as pinger on 9 or 27 kHz.
Surface Homing Devices: One RDF beacon (Oar Mfg.), self-powered, 27 mHz.
Sonars: Scanning sonar (Wesmar SS130), 160 kHz, 1,600 ft (488m) range, tiltable 90 degrees downward to act as echo sounder. Pinger mode in underwater telephone, 9 or 27 kHz, one second rep. rate, self-powered, 45 days duration.

Jettisonable Components: A 375 lb (170kg) lead weight is manually releaseable. Manipulator claw can be jettisoned.
Emergency Breathing: Four (two for each occupant) closed-circuit Drager units, each provides 45 minutes breathing duration.
Communications Procedure: Check with surface every 15 or 30 minutes. Abort dive if no surface contact established within 60 minutes.

System Readiness: Operational. AQUARIUS II & III are under construction.
Classification/Certification: ABS
Support Ship: M/V HUDSON HANDLER
Owner: Hyco Subsea Ltd.
P.O. Box 1059
Station A
Vancouver, B.C. V6C 2P1
Canada
Operator: Same as above
Builder: International Hydrodynamics Ltd.
Vancouver, B.C.
Canada
Point-of-Contact: Robert J. Starr
Address same as owner
Telephone: (604) 681-0342
Telex: 04-55465

ARGUS

CHARACTERISTICS

Length.....6m (19.7 ft)
Beam.....2.5m (8.2 ft)
Height.....3.7m (12.2 ft)
Draft.....2.5m (8.2 ft)
Weight (dry).....8.5t (9.4 tons)
Operating Depth..600m (1,969 ft)
Collapse Depth...1,000m (3,281 ft)
Launch Date.....1975

Hatch Diameter.....52cm (20.5 in.)
Life Support Duration.....216 man hrs
Total Power.....36 kWh
Speed: Cruise (kts/hrs)..1/7
Max (kts/hrs).....4/NA
Crew: Pilot(s).....2
Observer(s).....1
Payload.....300kg (662 lbs)
Color.....Yellow

Pressure Hull: Spherical shape, 2.2m (7.2 ft) ID, 18cm (0.7 in.) thick equivalent to HY-80 steel.
Power Source: Lead acid batteries, pressure compensated, consisting of 90 each 2 V cells producing 28 V at 1,200 amp-hr capacity.
Maneuvering Control: Static: MBT of 1.4m^3 (49 ft^3) capacity; VBT of 130kg (286 lbs) capacity. Dynamic: Two fixed, reversible screw-type propellers mounted p/s on the stern.
Pitch/Trim: Soft bladders forward and aft can be differentially filled with oil to provide ±15 degrees up/down bow angles.
Life Support: Five flasks of O_2 of 10 l. (10.5 qts) capacity each are bled continuously into hull. CO_2 is removed by scrubbing through CaOH for a period of 10-15 minutes every 30 minutes. Every 30 minutes the following properties are monitored: O_2, CO_2, temperature, humidity, pressure. Both O_2 and CO_2 monitors have backup monitoring devices.
Viewing: Four viewports total, three forward on bow and one on starboard side adjacent to sail. All have an ID of 14cm (5.5 in.).
Lift Point(s): One aft of sail "C" shaped hook with opening forward. Minimal opening 10cm (3.9 in.), 1.25cm (0.5 in.) thick, 12.5cm (4.9 in.) total length. A second circular orifice located aft of sail and is 7cm (2.75 in.) ID and made of 5.7cm (2.24 in.) thick plate steel.
Life Jackets: Three, inflatable
Surface Lights: One, flashing white light, 1.2m (3.9 ft) above water surface.
Fire Extinguisher: One, dry chemical.
Emergency Food and Water: Food and water equal to life support duration. Five l. (5.3 qts) of water and space craft type rations. Protective (thermal) clothing being investigated.
Medical Supplies: First aid kit.
Surface Communications: CB and VHF transceivers, both operate off main batteries. Range of VHF 3.7-5.6km (2-3nm).
Sub-Surface Communications: One underwater telephone, 17 kHz, CW, operates off main batteries has emergency power supply. Two transducers, one on top and one on keel of vehicle.
Jettisonable Components: A 200kg (441 lbs) lead weight is manually droppable. MBTs can be blown at operating depth.
Emergency Breathing: Closed circuit breathing sets provide one hour breathing duration for each occupant.
Communications Procedure: Check with surface every 30 minutes; if no contact in 60 minutes, dive is aborted.

System Readiness: Undergoing sea trials.
Classification/Certification: None
Support Ship: Ship of opportunity
Owner: Academy of Sciences USSR
Moscow

Operator: P.P. Shirshov, Institute of Oceanology
Academy of Sciences USSR
1 Letnay St., Moscow 109387
USSR

Builder: Same as above.

Point-of-Contact: Mr. A. Monin, Director
Institute of Oceanology USSR
Address same as above
Telephone: 233-55-76
Cable: G-387 OCEANOLOGIYA

AUGUSTE PICCARD

CHARACTERISTICS

Length.....93.5 ft (28.5m)
Beam.....13 ft (4m)
Height.....24 ft (7.3m)
Draft.....13 ft (4m)
Weight (dry).....185.2 tons (168t)
Operating Depth..2,297 ft (700m)
Collapse Depth...4,921 ft (1,500m)
Launch Date.....1963

Hatch Diameter.....29.5 in. (75cm)
Life Support Duration.....90 man days
Total Power.....740 kWh
Speed: Cruise (kts/hrs)..6/14
Max (kts/hrs).....3.6/15
Crew: Pilot(s).....6
Observer(s).....3
Payload.....5 tons (4.5t)
Color.....Dayglow orange above waterline, gray below

Pressure Hull: Cylindrical shape with two hemispherical end caps of Aldur 55/68 steel. Cylinder is 1.5 in. (3.8cm) thick, 10.25 ft (3.1m) OD and 59.7 ft (18.2m) long. Total length (including end caps) is 64.95 ft (19.8m).
Power Source: Lead acid batteries inside pressure hull and two Caterpiller Marine diesel engines driving two 85 kWh generators. Emergency power is provided for navigation, life support and underwater telephone.
Maneuvering Control: One, reversible, stern propeller (75 hp), fitted with a Kort nozzle trainable in the horizontal plane. Dive planes forward.
Pitch/Trim: Bow angles of ±15 degrees are attainable by differentially filling internal trim tanks, 2 fwd/2 aft; 80 ft^3 ($2.2m^3$) capacity in each pair.
Life Support: Seven flasks of compressed O_2 carried in hull. Each flask has a capacity of 2,040 ft^3 ($57m^3$) at STP. Monitors for O_2, CO_2, CO, H_2, freon, temperature, humidity and pressure. O_2, CO_2, H_2 and CO are continuously monitored and have an audio and visual warning when recommended tolerances are exceeded. CO_2 is removed by natural convection current passage through LiOH panels.
Viewing: Forty three viewports total, but only three in the bow are used for viewing. One TV camera (Hydro Products TC-125-SIT) mounted on pan & tilt device.
Lift Point(s): Towing bridle carried on support ship must be attached to towing points forward in order to attain a 30 ton (27.2t) lift.
Lighting (underwater): Two, 250 watt, thallium iodide.
Life Jackets: Seven, not selected at time of survey.
Distress Flares: Will be carried in hull.
Radar Reflector: Will be carried.
Surface Lights: Amber flashing, 90 flashes/min., self-powered. Also will carry main steaming light, p/s bow lights, forward and stern steaming lights.
Anchor: Will carry, capable of anchoring in 170 ft (37m) depth.
Fire Extinguisher: Six, dry chemical. Halon drench system.
Emergency Food & Water: Is equal to total life support duration. Also will carry some form of protective clothing.
Surface Communications: VHF/FM (Konel Gemini III), 12 channels 156-157 mHz. HF, SSB transceiver will also be carried.
Sub-Surface Communications: Two systems carried. Prime system (Mesotech 703A) operates on 8 or 27 kHz, secondary (Straza ATM 504A) on 8.3 to 10.7 kHz. Transducer topside and on keel. Dive does not terminate if communications are lost during hours scheduled to dive.

Surface Homing Devices: None at present; will include at later date.
Sonars: Pingers: One, 37 kHz. Scanning sonars: Two, one mounted topside; one on keel. Topside: Straza CTFM (Mod. 503), 87 to 72 kHz, 360 degree scan, 1,600 ft (488m) max. range. Keel: Wesmar SS1405. Side Scan Sonar: One, EG&G (Mod. Mark 1B), 105 ± 10 kHz, max. range 1,640 ft (500m).
Marker Buoys: Manually releaseable buoy containing radio beacon (2,182 kHz) and flashing xenon strobe light attached to vehicle by 2,500 ft (762m) of line.
Life Rafts: Two, six person capacity each.
Emergency Buoyancy: Manually (via hydraulic) droppable 7 ton (6.4t) weight.
Emergency Breathing: Twelve full face masks, which can plug into any of 18 quick-connect sockets, draw off 660 ft^3 (18.5m^3) of compressed air at STP from piping running throughout submersible. Two face masks in vehicle control area allow user mobility. Six, standard scuba sets for rescue.
Egress Procedure (underwater): Facilities are available to flood pressure hull and allow personnel to exit using the reserve scuba.

System Readiness: Sea trials
Classification/Certification: Will be classed according to Canadian Ministry of Transport and ABS.
Support Ship: None at time of survey; will use ship of opportunity. Ultimately seeking independent operations.
Owner: Horton Maritime Explorations, Ltd.
20 Brooksbank Avenue
No. Vancouver, B.C. V7J 2B8
Canada
(604) 980-8591
Operator: Same as above
Builder: Giovanola Bros.
Monthe, Switzerland
Point-of-Contact: Mr. Donald Morecombe
(Address same as above)
Telephone: (604) 980-8591

BEAVER

CHARACTERISTICS

Length.....24 ft (7.3m)	Hatch Diameter.....25 in. (64cm)
Beam.....9.5 ft (2.9m)	Life Support Duration.....360 man hrs
Height.....10.3 ft (3.1m)	Total Power.....44 kWh
Draft.....6.6 ft (2.0m)	Speed: Cruise (kts/hrs).....2.5/10
Weight (dry).....17 tons (15.4t)	Max (kts/hrs).....5.7/NA
Operating Depth....2,700 ft (823m)	Crew: Pilot(s).....1
Collapse Depth.....NA	Observer(s)/diver(s)..1/3
Launch Date.....1968	Payload.....2,000 lbs (907kg)
	Color.....Orange

Further design, operational and equipment details are not available until the major refitting program is completed.

System Readiness: Undergoing major overhaul which includes installation of a plastic bow dome. Planned to be operational by spring of 1977.
Classification/Certification: Will be submitted for ABS classification.
Support Ship: Ship of Opportunity
Owner: International Underwater Contractors, Inc.
Apartado Postal 1450
Panama 1, Panama
Operator: International Underwater Contractors, Inc.
P.O. Box 95
City Island, N.Y. 10464
Builder: North American Rockwell Corp.
Seal Beach, Ca.
Point-of-Contact: Mr. Booker T. Washington
International Underwater Contractors
264 Fordham Place
City Island, N.Y. 10464
Telephone: (212) 885-0600
Cable: TECHDIVER NY
Telex: 147242

PAUL R. BURKHOLDER I

CHARACTERISTICS

Length.....6.93m (22.7 ft)	Hatch Diameter.....52cm (20.5 in.)
Beam.....3.5m (11.5 ft)	Life Support Duration.....96 man hrs
Height.....4.35m (14.3 ft)	Total Power.....50 kWh
Draft.....2.1m (6.9 ft)	Speed: Cruise (kts/hrs)..2/NA
Weight (dry).....14t (15.4 tons)	Max (kts/hrs).....4.5/NA
Operating Depth..300m (984 ft)	Crew: Pilot(s).....1
Collapse Depth...500m (1,640 ft)	Observer(s).....1
Launch Date.....1971	Payload.....300kg (662 lbs)
	Color.....Yellow

Pressure Hull: Cylindrical shape with hemispherical end caps, 1.9m (6.2 ft) diameter, 4.84m (15.9 ft) total length. Cylindrical conning tower welded to hull.
Power Source: Lead acid batteries inside pressure hull provide 210 amp-hr at five hr discharge rate.
Maneuvering Control: Two, p/s, continuously-variable thrusters mounted amidships and rotatable 360 degrees in the vertical plane provide all maneuvering capability.
Pitch/Trim: A maximum of ±30 degrees up/down bow angle can be obtained by hydraulically shifting a 150kg (331 lb) steel weight forward or aft.
Life Support: Four O_2 bottles of five l. (1.3 gal) volume each are carried within the pressure hull. CO_2 is removed by scrubbing through soda lime. Monitors for O_2, CO_2, temperature and pressure.
Viewing: Nine viewports total: four are in the forward end cap; five girdle the conning tower. Television camera with video recorder is carried inside pressure hull.
Manipulator(s): One, six degrees-of-freedom, 1.9m (6.2 ft) maximum extension, hydraulically-powered, parallel jaws type claw with hydraulic hammer. Not jettisonable.
Lift Point(s): Two metal padeyes forward and aft of conning tower with circular openings approximately 2.54cm (1 in.) diameter.
External Lighting: One, trainable, 1,000 w, quartz iodide light on bow.
Life Jackets: Two, (Drager Mfg.) inflatable life jackets that also provide emergency breathing.
Distress Flares: Four, red flares carried inside pressure hull.
Surface Lights: One, flashing red light, 1.5m (4.9 ft) above water surface, 9 hrs duration, self-powered.
Anchor: Canvas sea anchor
Fire Extinguisher(s): One, dry chemical
Emergency Food & Water: 3.8 l. (1 gal.) potable water, rice and dried fish.
Medical Supplies: First aid kit.
Automatic Deballasting: Main ballast tanks will be automatically blown dry unless stopped by pilot every 15 minutes. Also, if vehicle transgresses below operating depth, the MBTs will again be emptied.
Surface Communications: CB, 27 mHz, 3-5nm (5.6-9.3km) range. Hatch must be opened to use CB.
Sub-Surface Communications: One underwater telephone, 8.5 kHz.
Sonar(s): Echo sounder with two transducers, one is directed forward to serve as an obstacle avoidance sonar; the second is directed downward for height above the bottom measurements. Frequency: 50 kHz, range of echo sounder is 310m (1,017 ft), measurement range of forward looking transducer is 150m (492 ft).

Marker Buoy(s): Two buoys made of syntactic foam are mechanically released by the pilot and allowed to ascend to the surface. The buoys are connected by a light line to each other and similar lines run back to the vehicle. A stronger lift line can be slid down the marker buoy line to achieve retrieval by the support craft.
Jettisonable Components: A 100kg (221 lb) cargo net (used for storage of coral) can be mechanically jettisoned by the pilot.
Emergency Breathing: Two (Drager Mfg.) closed circuit breathing devices provide 30 minutes duration each.
Communications Procedure: Check with surface craft according to pilot's discretion.

System Readiness: Operational
Classification/Certification: Germanischer Lloyds
Support Ship: Ship of opportunity
Owner: Kuofeng Ocean Development Corp.
3rd fl., 4-1 Chang An E. Rd. Sec. 1
Taipei, Taiwan
Republic of China
Builder: Machinenbau Gabler
Lubeck, West Germany
Operator: Same as owner.
Point-of-Contact: Mr. Telo Ma or Mr. H.Y. Miao
(Address same as owner)
Telephone: 581-3431 or 551-3416 (Taipei)
Cable: AORTA, Taipei

CYANA

CHARACTERISTICS

Length.....5.7m (18.7 ft)
Beam.....3.04m (4.5 ft)
Height.....2.10m (6.9 ft)
Draft.....2.08m (6.8 ft)
Weight (dry).....8.5t (9.4 tons)
Operating Depth..3,000m (9,842 ft)
Collapse Depth...3,900m (12,795 ft)
Launch Date.....1970

Hatch Diameter.....400mm (15.7 in.)
Life Support Duration.....216 man hrs
Total Power.....47 kWh
Speed: Cruise (kts/hrs)..1/10
Max (kts/hrs).....2/5
Crew: Pilot(s).....1
Observer(s).....2
Payload.....199kg (490 lbs)
Color.....Yellow

Pressure Hull: Spherical shape composed of Vascojet 90 steel, 2,001mm (79 in.) OD and 30.5mm (1.2 in.) thick.
Power Source: Lead acid batteries, pressure compensated, 62 cells rated at two V each with a 380 amp-hr capacity. Both 120 VDC and 24 VDC are supplied.
Maneuvering Control: Static: Vehicle is negatively buoyant when launched and held on surface by three buoys until ready to dive. Weight is released at operating depth to attain neutral buoyancy. Additional weight (iron shot) is released to surface. Negative buoyancy can be obtained by introducing sea water into one or all of four titanium spheres. Dynamic: Two, screw-type, reversible, one-speed propulsers mounted p/s forward; 2.5 hp each.
Pitch/Trim: Mercury can be transferred forward or aft to obtain up/down angles of ±28 degrees.
Life Support: Three flasks of O_2 with volume of seven l. (7.4 qts) each are carried in the pressure hull and bled continuously into the sphere. CO_2 is removed by scrubbing through soda sorb. O_2, CO_2, temperature, humidity and pressure are monitored and checked every 30 minutes. Cabin air is also blown through silica gel to lower humidity.
Viewing: Two large viewports of 110mm (4.3 in.) ID are located forward just below the equatorial axis. A smaller camera viewport is situated between and just above the two large ports. An external, fixed, TV camera is carried and includes a video recorder.
Manipulators: One, jettisonable, hydraulically-powered, 1.8m (6 ft) maximum length, five degrees-of-freedom with a lift capacity of 20kg (44 lbs) at maximum extension and 50kg (110 lbs) maximum lift. Claws and terminations include parallel jaws, scissors and a rotary steel cutter.
Lift Point(s): The emergency lift point consists of an 8mm (0.3 in.) diam. stainless steel wire rope with one end attached to the main lift point and the other end terminating at the stern in a 15cm (5.9 in.) diam. loop. The cable is capable of two t (2.2 tons) lift. A two-pronged, fishhook-like, spring-loaded, toggle device is carried aboard the support ship. This device is designed to be carried down to CYANA by another vehicle and inserted into the loop for surface retrieval to a depth where additional lift lines may be attached.
External Lighting: Three lights total, one of 500 w and two of 750 w, all are quartz iodide and mounted on brow.
Life Jackets: Three, inflatable (Fenzy type)
Life Rafts: Three, one-man, inside hull.
Distress Rockets: Ten, red color, stored inside hull.

Radar Reflector: One, tetrahedron-shaped, permanently affixed, 0.6m (2 ft) above water line.
Surface Lights: Flashing white, 1/sec rep. rate, 0.6m (2 ft) above surface, pilot activated, operates off main batteries.
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Three day supply food (life boat-type rations) and 9 l. (9.5 qts) water. Occupants' clothes are chemically treated to be inflammable.
Surface Communications: One VHF, 27 mHz, two channels, 5-10nm (9-18 km) range, powered off main batteries.
Sub-Surface Communications: Two systems, one was designed and built by the French Navy. It operates on 8 kHz and also serves as a transponder and echo sounder. The second (CSF Thompson Mfg.) operates on 8 kHz and has CW capability. Both transducers are mounted topside.
Surface Homing Devices: Self-powered, 27 mHz, five day duration, radio beacon (OAR Model) automatically activates upon surfacing. RDF on support ship.
Sonars: Straza CTFM Sonar Model 500, range 10-1,500 yds (9-1,372m), 360 degree scan, interrogates between 55-40 kHz, can act as transponder in 87-72 kHz transmitting range. Pingers: One, (Burnett Electronics Mod. 597), 37 kHz, salt water activated, rep. rate 2/sec., self-powered. Echo Sounder: Downward-looking, 120 kHz, 200m (656 ft) range (Data Marine Mfg.). Transponder: One, (CSF Thompson), self-powered interrogation frequency 16 kHz, responding frequency 17 kHz.
Jettisonable Components: Batteries: 185kg (408 lbs); manipulator: 70kg (154 lbs); descent weight: 120kg (264 lbs); trim weight (shot): 200kg (441 lbs); mercury 95kg (210 lbs).
Emergency Breathing: Three Fenzy special O_2 breathing devices of 3 hours each duration.
Communications Procedure: Communications check with surface every 30 minutes; abort dive if no contact within 45 minutes.

System Readiness: Operational
Classification/Certification: None, under review by Veritas
Support Ship: Ship of opportunity
Owner: Centre National Pour L'Exploration des Oceans (CNEXO), Paris
21 de Toulon - Est
P 31 30 LaGarde
France
Operator: CNEXO
Address same as above
Builder: Centre de L'Etudes Marine Avances (CEMA)
Point-of-Contact: Claude Caillart
CNEXO, Toulon
(Address same as owner)
Telephone: (94) 27-30-10
Telex: 430037

DEEP QUEST

CHARACTERISTICS

Length.....39.9 ft (9.3m)	Hatch Diameter.....20 in. (51cm)
Beam.....19 ft (5.8m)	Life Support Duration.....204 man hrs
Height.....13.25 ft (4.04m)	Total Power.....230 kWh
Draft.....8.6 ft (1.0m)	Speed: Cruise (kts/hrs)..2/18
Weight (dry).....52 tons (47t)	Max (kts/hrs).....3/12
Operating Depth..8,000 ft (743m)	Crew: Pilot(s).....2
Collapse Depth...13,000 ft (3,962m)	Observer(s).....2
Launch Date.....1967	Payload.....3 tons (2.7t)
	Color.....White, orange sail and rudder

Pressure Hull: Bi-sphere shape, each sphere is 0.895 in. (2.3cm) thick, 7 ft (2.1m) OD and made of 18% nickel, KSI grade maraging steel. Spheres are welded together and connection between the two is a 20 in. (51cm) diam. opening.
Power Source: Main power is derived from two 115 VDC, pressure-compensated lead acid batteries mounted below and between the bi-spheres. Two 28 VDC silver zinc batteries are carried in the pressure hull to provide 3.6 kWh emergency power.
Maneuvering Control: Forward and reverse thrust is from two, reversible, stern-mounted, 7.5 hp AC motor-driven propellers. Vertical thrust is from two fore and aft mounted, 7.5 hp AC motors and ducted propellers. Lateral thrust is from fore and aft mounted water jets powered by two 7.5 hp, AC motors. A rudder and stern planes provide additional underway steering control.
Pitch/Trim: A 30 degree up or down bow angle can be produced by transferring 1,400 lbs (652kg) of oil and mercury between two fore and aft mounted, 18 in. (46cm) diam., spherical, steel tanks. A 10 degree port or starboard list can be attained by transfer of 828 lbs (375kg) of mercury between two 15 in. (38cm) diam. tanks. Both trim and list systems are pressure-compensated.
Life Support: Four 0.37 ft^3 (0.03m^3) volume tanks supply oxygen for normal usage. Carbon dioxide is removed by LiOH. Oxygen level is automatically monitored and regulated. Emergency breathing is by four full face masks connected to an oxygen-demand system for survival periods of 12 man hrs. Temperature and humidity are automatically regulated. Warning light and buzzer activate when O_2 and CO_2 reach prescribed values. Heaters available, but rarely required. Trace contaminents can be monitored, but experience shows it to be unnecessary.
Viewing: Two acrylic plastic viewports are provided; one is located on the axis of the forward sphere and is a few degrees below the horizontal. It is 9 in. (23cm) OD, three in. (8cm) ID. The second is in the aft sphere and looks directly downward. It is 15 in. (38cm) OD, five in. (13cm) ID. The aft viewport is equipped with an optical remote viewing system of 180 degree objective in the vertical and 360 degree in the horizontal. Four television cameras: Three on pan and tilt devices, one fixed.
Manipulator(s): Two manipulators, six degrees-of-freedom, jettisonable, total length 72 in. (1.8m), lift capacity of grip rated at 300 lbs (226kg), parallel jaws-type claw.
Lift Point(s): A rope bridle is rigged p/s between two lift points aft of the sail and tied off to a wire line running between sail and rudder. Attachment of lift hook to this bridle can lift vehicle to surface in nose-down position.

Lighting (underwater): Between 10 to 12 lights are carried. Eight are fixed on the bow and are 500 watts each. Two illuminate area under after hatch.
Life Jackets: Four, inflatable
Distress Flares: Very pistol, four shells, parachute-type flares, red, carried outside of pressure hull.
Surface Lights: One (Benthos Mod. 2001), flashing white strobe (1 flash/2 secs) mounted six ft (1.8m) above water surface, self-powered, 40 hrs duration, pressure-activated switch.
Fire Extinguisher: Two, dry chemical
Emergency Food & Water: Life boat type rations carried to equal 204 man hrs life support duration. One gal. (3.8 l.) water carried.
Automatic Deballasting: If main power fails, 1,800 lbs (815kg) of iron shot will drop.
Surface Communications: VHF transceiver, 9 channels (plus weather) Heathkit 10 watt.
Sub-Surface Communications: One, (Straza Mod. 504) transmits/receives on 8.0875 kHz, operates off main batteries, has two transducers, one topside and one on keel.
Surface Homing Devices: 1) Emergency Radio Beacon (Martek Mod. EB-1B), pilot activated, self-powered, 48 hrs duration, 5.6 V, 121.5 mHz (compatible with Coast Guard Rescue frequency). 2) Submersible Beacon Transmitter (OAR Mod. ST 200) self-powered, 12-100 hrs duration, automatically transmits when reaches surface. Used in conjunction with support craft RDF to determine that sub has surfaced.
Sonars: Pingers: 2 each, both 48 hrs duration, 27 kHz, 2 sec. rep. rate, and self-powered. One pinger is omnidirectional and one is directional looking upward in a 30 degree cone. Omnidirectional pinger is to maintain general contact with sub from surface ship. Unidirectional pinger is used to position support ship directly over submersible for position fixing. CTFM Sonar: (Straza Mod. 500) with ranging and transponder interrogation capability, 87 to 72 kHz, 1,500 yd (1,372m) range.
Emergency Buoyancy: Iron shot: 1,800 lb (815kg); mercury: 800 lbs (362kg); forward battery cells: 3,500 lbs (1,132kg)
Emergency Breathing: A closed-circuit, four-man system using pure oxygen provides three hrs duration/man. All breathing devices draw off the same regulator. CO_2 is scrubbed within the system.
Communications Procedure: Check with surface every 15 minutes. Loss of communications is not an abort situation. Vehicle is given permission to dive for a specific time period; if no contact after this time period, the dive is aborted.

System Readiness: Submersible has not dived since Nov. 1973. TRANSQUEST is operational and has been supporting the DSRV test and training programs.
Classification/Certification: Was USN certified, but tenure has expired.
Support Ship: M/V TRANSQUEST
Owner: Lockheed Ocean Laboratory
3380 N. Harbor Drive
San Diego, Ca. 92101
Telephone: (714) 298-8245
Operator: Lockheed Ocean Laboratory
(Address same as above)
Builder: Lockheed Missiles & Space Co.
Sunnyvale, Ca.
Point-of-Contact: Mr. R.A. Tyrrell
Lockheed Ocean Laboratory
(Address and telephone number same as owner)

DEEP SUBMERGENCE RESCUE VEHICLE (DSRV) 1 & 2

CHARACTERISTICS

Length.....49 ft 4 in. (15m)
Beam.....8 ft 2 in. (2.5m)
Height.....11 ft 5 in. (3.5m)
Draft.....9 ft 11 in. (3m)
Weight (dry).....38.2 tons (34.6t)
Operating Depth..5,000 ft (1,524m)
Collapse Depth...7,500 ft (2,286m)
Launch Date.....1970 & 1971

Hatch Diameter.....Upper: 28 in. (71cm)
Lower: 24.87 in. (63.2cm)
Life Support Duration.....384 man hrs
Total Power (kWh).....58 kWh
Speed: Cruise (kts/hrs).....NA
Max (kts/hrs).....4.1/NA(#2) 3.9/4 (#1)
Crew: Pilot(s).....2
Life Support Operators.2
Rescuees.....24 (ultimately)
Payload.....NA
Color.....Olive drab

Pressure Hull: Three spheres composed of HY-140 steel, 88.6 in. ID (225cm), 0.7 in. (1.8cm) nominal thickness. Skirt (stub) 1 in. (2.54cm) thick. Transfer skirt 0.41 in. (1.04cm) thick.

Power Source: Two, silver zinc 112 VDC batteries, pressure-compensated, rated at 525 amp-hrs for each battery. Silver zinc batteries, inside hull, 28 VDC at 70 amp-hrs, provides power for underwater telephone, surface communications, interior communications, alarm panel, CO_2 scrubber, O_2 control, tracking (pinger/transponder) beacon, jettisoning systems, main ballast air blow, some mating valves, internal lighting, homing transponder drop, and main circuit breakers.

Maneuvering Control: Main forward propulsion is provided by a 4 ft (1.2m) diameter, stern-mounted, reversible propeller, 15 hp. A shroud around the propeller can be tilted to provide pitch and yaw motion. Four ducted thrusters, two vertical and two horizontal, each is reversible and 7 1/2 hp.

Pitch/Trim: Mercury trim system can provide $\pm$45 degrees bow angle. Roll angles of $\pm$45 degrees can be obtained by transferring mercury.

Life Support: O_2 carried inside hull 360 ft^3 (10m^3) at 3,000 psi (210kg/cm^2). LiOH is used to scrub CO_2. O_2, CO_2, temperature, humidity and pressure are monitored every 15 minutes and recorded every 30 minutes.

Viewing: Five total. Two in control (forward) sphere, one looks down and forward and one looks down and aft but is inaccessible. Three in mid-sphere, two are located p/s and look forward and down, one is in the lower hatch cover and looks directly down. Six television cameras, five are external and one is inside the hull (video recorder optional).

Manipulator(s): One, hydraulically-powered, six degrees-of-freedom, parallel jaws type claw (with cable-cutting and water jetting capability), jettisonable.

Lift Point(s): Two points located on top of vehicle, one forward and one aft. Each point consists of a 1.25 in. (3.2cm) thick shackle which rotates forward or aft on a pin. The internal configuration is that of a rectangle with one end a hemisphere, maximum ID is 3.6 in. (9.4cm); minimum ID is 2 in. (5cm). Each shackle is sufficiently strong to lift the vehicle to some point beneath the surface when divers can attach lifting lines.

External Lighting: Seventeen lights total. Thirteen are mercury vapor lights of 175 watts each; four are quartz iodide of 75 watts each.

Life Jackets: Twenty-eight, inflatable.

Surface Lights: One, xenon flashing white, self-powered, pressure-activated, one flash every two seconds. Duration is 40 hrs plus.

Fire Extinguisher: Three, carbon dioxide
Emergency Food & Water: Ten cans of water, 10 pts (4.7 l.) capacity each
Medical Supplies: Three first aid kits
Surface Communications: One UHF radio transceiver, 20 watts, multi-channel, frequency is 225 to 399.95 mHz, 15 nautical mile (28km) range.
Sub-Surface Communications: One, underwater telephone, 8.0875 kHz, (Ametek/Straza Mfg.), CW, two transducers: top is conical beam, bottom is omnidirectional.
Surface Homing Devices: Radio transceiver can be used as an emergency radio beacon.
Sonars: Two CTFM scanning sonars (Ametek/Straza Mfg.), one is trained to scan horizontally (with transponder interrogation capability), 4,500 ft (1,372m) range, CRT display, 72 to 87 kHz frequency; the second is trained to scan vertically and has the same characteristics as the horizontal CTFM. One short range sonar, 15 ft (4.6m) range on frequency of 1 mHz; 150 ft (45.7m) on frequency of 116 kHz. One altitute/depth sonar with recorder, 12,000 ft (3,658m) on 24 kHz frequency. One Transponder Interrogator sonar, 15,000 ft (4,572m) range, 7 kHz, receiving from 12.5 to 17 kHz. Doppler Sonar navigator, 300 kHz. Tracking Transponder/Pinger 15,000 ft (4,572m) range, can ping continuously (once every five seconds) and respond between 12.5 to 17.0 kHz at 50 Hz steps. Two, droppable, homing transponders, 15,000 ft (4,572m) range, 12.5 to 17.0 kHz receive/respond range.
Directional Antennae: One, with bearing display, to be installed at a later date.
Jettisonable Components: Manipulator, pan & tilt units (two each). Trim and list mercury of 3,450 lbs (1,565kg) total weight in air.
Emergency Breathing: Twenty-eight full face masks, closed-circuit, drawing off O_2 and N_2 tanks, exhale through LiOH. This is the same system used for the normal life support.
Egress Procedure: Crew can exit to 160 feet (49m) depth by pressurizing central sphere to ambient.
Communications Procedure: Surface contact check every 30 minutes, if no contact can be established within 30 minutes, the dive is aborted.

System Readiness: Undergoing final operational and evaluation tests.
Classification/Certification: USN certified to 5,000 ft.
Support Ship: Nine fleetsubmarines and two ASRs.
Owner: U.S. Navy
Operator: Submarine Development Group One
San Diego, Ca. 92132
Builder: Lockheed Missiles & Space Co.
Sunnyvale, Ca.
Point-of-Contact: Commander
Submarine Development Group One
San Diego, Ca. 92132
Telephone (714) 225-6583

DEEPSTAR-2000

CHARACTERISTICS

Length	19.75 ft (6m)
Beam	8 ft (2.4m)
Height	8.5 ft (2.6m)
Draft	5 ft (1.5m)
Weight (dry)	8.75 tons (7.9t)
Operating Depth	2,000 ft (610m)
Collapse Depth	4,130 ft (1,259m)
Launch Date	1969
Hatch Diameter	16 in. (41cm)
Life Support Duration	144 man hrs
Total Power	26.5 kWh
Speed: Cruise (kts/hrs)	1/8
Max (kts/hrs)	3/2
Crew: Pilot(s)	1
Observer(s)	2
Payload	500 lbs (227kg)
Color	Yellow above waterline, black below waterline

Pressure Hull: Cylindrical shape with hemispherical end caps, 5 ft (1.5m) diam., 10 ft (3.1m) length, 0.75 in. (1.9cm) thickness, HY-80 steel.
Power Source: Lead acid batteries, pressure compensated. One battery at 120 V/ 150 amp-hr; two at 28 V/150 amp-hr.
Maneuvering Control: Two main thrusters (propellers) in stern (five hp ea.), reversible and continuously variable. Two p/s vertical thrusters and two horizontal thrusters (forward/aft). Stop distance from speed of one knot: 20 ft (6.1m); 180 degree pivot time: 30 sec; 6 ft (1.8m) vertical excursion rate; can maintain position in 0.5 knot transverse current. Static depth control: $\pm$1 ft (0.3m). Static descent rate: 0.6 knot.
Pitch/Trim: Bow angle of $\pm$15 degrees by moving batteries forward or aft.
Life Support: Two O_2 flasks carried in pressure hull. CO_2 scrubber compound: LiOH. Scrubber powered off main power supply; has back-up ni-cad battery in hull. Monitors for O_2, CO_2, temperature, humidity and cabin pressure.
Viewing: Two large, 4 in. (10cm) ID; 7 1/16 in. (17.9cm) OD viewports looking forward and 19 degrees downward from the horizontal. One small, 2 in. (5cm) ID, 3.75 in. (9.5cm) OD, viewport between large ports used for photography.
Manipulators: One jettisonable, hydraulic-powered, three degrees-of-freedom, 4.25 ft (1.3m) total length. Orange peel type claw 9 in. (23cm) maximum opening. Total grasping capacity about 200 lbs (91kg).
Lift Point(s): One 7 in. (17.8cm) ID steel ring 3.5 in. (8.9cm) thick. Ring is held in place by two steel cables each attached to padeyes welded to the hull. Ring is forward of the sail amidship and on the longitudinal centerline. Ring is not fixed upright, but lays on its side during dive.
External Lighting: Seven lights total. Two under brow are each 1,000 w incandescent. One atop brow is a 500/700 w incandescent. Two lights on each of two extendable p/s booms; each boom has one 1,000 w incandescent and one 250 w thallium iodide light. Lights are friction-fitted into boom and will pull free and disconnect if snarled. Booms are 14.25 ft (4.3m) long and extend 10.8 ft (3.2m) from leading edge of brow.
Life Jackets: Three, inflatable.
Distress Flares: Six, 20mm, red parachute flares carried in sealed box inside pressure hull.
Smoke Pots: Six, yellow smoke, carried in sealed box inside pressure hull.
Radar Reflector: Corner reflector, mesh carried in pressure hull. Extends 5.5 ft (1.7m) above waterline. Sail (fiberglass) is lined inside with aluminum foil to increase radar reflectivity.

Surface Lights: One self-powered, white, flashing xenon strobe atop sail, 48 hr duration, one second rep. rate (OAR Mod. XF-501).
Fire Extinguisher: One, dry chemical
Emergency Food & Water: "C" rations and 2 qts (1.9 l.) of water. Approximately two days duration.
Surface Communications: FM radio, 25nm (46 km) range.
Sub-Surface Communications: One underwater telephone (Westinghouse Mod. 415A), frequency of 8.0875 kHz, can transmit CW.
Surface Homing Devices: FM radio can be pulsed or set to transmit CW for radio direction finder.
Sonars: Pingers, two mounted inside sail, one is 27 kHz, self-powered, one second rep. rate and 48 hrs duration; the other is 12 kHz and powered off the main batteries. Up/down looking, 12 kHz transducers displaying on a strip chart recorder. Acoustic directional antennae (Heele Mod. 6550) mounted on leading edge of brow receives frequencies from 25 kHz through 40 kHz. Obstacle avoidance sonar (Westinghouse Mod. A-38) with frequency of 380 kHz. Transponder: 23-27 kHz, powered off main batteries.
Life Rafts: Three each, one man capacity.
Emergency Buoyancy: Air blow of main ballast tanks at 2,000 ft (610m) provides 500 lbs (226kg) positive buoyancy. Jettison: High pressure air bottles - 500 lbs (226kg), batteries - 1,250 lbs (566kg), instrument brow - 500 lbs (226kg).
Emergency Breathing: Three, Westinghouse closed-circuit Min-o-lungs. Duration: one hr each.

System Readiness: At time of survey, DEEPSTAR-2000 had not dived since 1972. Approximately two months would be required to bring it up to 100% operating capability. It was sold in the fall of 1975 to GO International.
Classification/Certification: ABS
Support Ship: NA
Owner: GO International
149 Place de l'Estaque
Marseille 16
France
Operator: Same as above
Builder: Westinghouse Ocean Research & Engineering Ctr.
P.O. Box 1488
Annapolis, Md. 21404
Point-of-Contact: Mr. Jean Mollard
GO International
(Address same as above)
Telephone: 46.13.56 Marseille

DEEPSTAR-4000

CHARACTERISTICS

Length.....20.25 ft (6.2m)
Beam.....8.2 ft (2.5m)
Height.....9.5 ft (2.9m)
Draft.....7.5 ft (2.3m)
Weight (dry).....11.6 tons (10.5t)
Operating Depth..4,000 ft (1,219m)
Collapse Depth...8,000 ft (2,438m)
Launch Date.....1965

Hatch Diameter.....15.75 in. (40cm)
Life Support Duration.....288 man hrs
Total Power.....45.6 kWh
Speed: Cruise (kts/hrs)..2/5
Max (kts/hrs).....3/NA
Crew: Pilot(s).....2
Observer(s).....1
Payload.....882 lbs (0.4t)
Color.....Yellow: Fairings
Red: Pressure Hull

Pressure Hull: Spherical shape, 78.75 in. (200cm) OD composed of HY-80 steel.
Power Source: Lead acid batteries, pressure compensated, 380 amp-hr.
Maneuvering Control: Eight thrusters total. Four provide main forward propulsion, two are lateral thrusters. All are 1.5 hp.
Pitch/Trim: Mercury is transferred between two cylinders located forward and aft to provide ±30 degrees bow angle.
Life Support: Two O_2 flasks of 1.16 ft^3 (33 l.) volume are carried. Two scrubbers, both use soda lime to remove CO_2. Monitors for O_2, CO_2, temperature, humidity and pressure.
Viewing: Three viewports, all look forward, two are 4.3 in. (11cm) ID, one is 1 in. (4.6cm) ID and is located between the two larger ports.
Manipulator: One, jettisonable, hydraulically-powered, five degrees-of-freedom, lift capacity of 80kg (177 lbs) at maximum extension of 1.5m (4.9 ft).
Lift Point(s): One (Details not available)
External Lighting: Five lights total. Three forward to illuminate viewing area, 300 w each. Two security flood lights of 150 w each.
Life Jackets: Three, inflatable.
Radar Reflector: One (Details not available)
Surface Lights: Two (Details not available)
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Equal to life support duration
Surface Communications: VHF, multi-channel. (Details not available)
Sonars: Final instrument suite will include various acoustic devices, but details unavailable at time of survey.
Marker Buoys: Two, automatic (Details not available)
Sub-Surface Communications: One (Not selected at time of survey)
Jettisonable Components: Security weight - 100kg (221 lbs); Four propellers - 120kg (265 lbs); Battery - 410kg (905 lbs); Manipulator - 200kg (442 lbs).
Emergency Breathing: Three (Fenzy Mfg.), each providing four hours per occupant.
Communications Procedure: No details available.

System Readiness: Undergoing refit, ready by late 1976.
Classification/Certification: ABS and Veritas
Support Ship: NA
Owner: COMEX
13275 Marseille Cedex 2
France
Operator: Same as above
Builder: Westinghouse Ocean Research and Development Laboratory
Annapolis, Maryland

Point-of-Contact: Gerard Chocteau or J.P. Marquinez
c/o COMEX
(Address same as Owner)
Telephone: 40.11.70 Marseille
Telex: 410985 COMEX MARSL

DIAPHUS

CHARACTERISTICS

Length.....19.8 ft (6.0m)
Beam.....6.5 ft (2.0m)
Height.....8.2 ft (2.5m)
Draft.....6.3 ft (1.9m)
Weight (dry).....5 tons (4.5t)
Operating Depth..1,200 ft (366m)
Collapse Depth...1,800 ft (549m)
Launch Date.....1974

Hatch Diameter.....19 in. (48.3cm)
Life Support Duration.....180 man hrs
Total Power.....16 kWh
Speed: Cruise (kts/hrs)..NA
Max (kts/hrs).....3/NA
Crew: Pilot(s).....1
Observer(s).....1
Payload.....900 lbs (408kg)
Color.....White conning tower and MBTs are international orange, p/s air tanks black

Pressure Hull: Cylindrical shape with conical after end cap and plastic bow dome. Composed of A516 Grade 70 normalized steel 7/16 in. (1.0cm) thick.
Power Source: Lead acid batteries in jettisonable, pressure-resistant pod. A total of 17 batteries, divided into five banks (three batteries each) to provide 36 volts, and into one bank (two batteries each) to provide 12 volts.
Maneuvering Control: A stern-mounted, reversible propeller provides fore/aft motion and is powered by a three hp Cushman golfcart motor. Dive plane and rudder (both manually operated) provide dynamic maneuvering control.
Life Support: Eight tanks of O_2 are carried in pressure hull. Each tank is 22 ft^3 ($0.6m^3$) capacity each at 2,150 psi ($150kg/cm^2$). CO_2 scrubber compound: LiOH. Three emergency cannisters are carried on each dive in addition to that already in the scrubber. Spare scrubber motor carried. O_2 monitored continuously (Bio Marine 222), CO_2 monitored every 30 minutes (Bacharack). Altimeter.
Viewing: Plastic bow dome 36 in. (91.4cm) diam., 2 in. (5.1cm) thick and protected by a 0.5 in. (1.3cm) thick plastic cover which free-floods with sea water. Seven viewports in conning tower 8 in. (20.3cm) OD.
Manipulator: One, non-jettisonable, three degrees-of-freedom with linear extension. Scissors-type claw 7 in. (17.8cm) maximum opening. Total arm length 5.3 ft (1.6m), 100 lbs (45kg) static lift maximum.
Lift Point: One, 1.5 in. (3.8cm) shackle with a 1 in. (2.5cm) pin. Shackle lays flat during dive, OD 7 in. (17.8cm) least ID 3 7/8 in. (9.8cm), max. ID 4.5 in. (11.4cm).
External Lighting: One (Birns & Sawyer), 150 w incandescent mounted on underside of dive plane to allow training in the vertical. One strobe light for photography (Subsea MK 150).
Life Jackets: Two, inflatable
Surface Lights: Xenon, white-flashing 44 in. (111.8cm) above water surface, self-powered on main batteries, one sec. rep. rate, 15 days duration (OAR SF501-100)
Fire Extinguisher: One, dry chemical
Medical Supplies: First aid kit.
Emergency Food & Water: Two gals (7.6 l) water. No emergency food supply.
Surface Communications: CB, five w, Layfette (HB 700), 23 channel.
Sub-Surface Communications: Two systems (one spare), Sub Comm 100S 20B and 200S 20B, 8 & 27 kHz frequency. Can also serve as pinger on 10 kHz. Power from main batteries and from emergency batteries in-hull. Surface contact made every 15 minutes; if no contact after 30 minutes, dive is aborted.

Surface Homing Devices: RDF signal powered from emergency battery system or main batteries. Transmits on 27.145 kHz. Receiver is an OAR "Finder's Receiver" F4206 and receives on 2.145 mHz.
Sonars: Emergency (Helle) pinger, 27 kHz, one sec. rep. rate. Operates off emergency power.
Marker Buoys: Surface buoy towed during every dive.
Emergency Buoyancy: Battery pod and portion of instrument rack manually jettisonable.
Emergency Breathing: Two scuba regulators draw off both main ballast air tanks.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: R/V GYRE
Owner: Texas A&M University
College Station, Texas 77843
Operator: Same as above.
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: Capt. T.K. Treadwell
Dept. of Oceanography
Texas A&M University
College Station, Texas 77843
(713) 845-7211

DOWB

CHARACTERISTICS

Length.....17 ft (5.2m)	Hatch Diameter.....20 in. (51cm)
Beam.....8.9 ft (2.7m)	Life Support Duration.....270 man hrs
Height.....11 ft (3.4m)	Total Power.....48 kWh
Draft.....5 ft (1.5m)	Speed: Cruise (kts/hrs)..1/8.3
Weight (dry).....9.5 tons (8.6t)	Max (kts/hrs).....2.5/4
Operating Depth..4,500 ft (1,372m)	Crew: Pilot(s).....1
Collapse Depth...10,000 ft (3,048m)	Observer(s).....2
Launch Date.....1968	Payload.....1,800 lbs (815kg)
	Color.....Red

Pressure Hull: Spherical shape, composed of HY-100 steel, 82 in. (208cm) OD and 0.935 in. (2.4cm) thick.
Power Source: Lead acid batteries in pressure-compensated container. Auxiliary power of 1.2 kw is provided to operate emergency controls.
Life Support: Two O_2 flasks, one containing 175 ft^3 (4.9m^3) at 2,350 psi (165kg/cm^2) the second containing 140 ft^3 (3.9m^3) at 2,000 psi (140kg/cm^2). CO_2 will be removed by scrubbing air through LiOH, 19.2 lbs (8.7kg) will be carried. Monitors for O_2, CO_2 and CO. Humidity controlled by silica gel, activated charcoal will be used for odor control.
Viewing: A 24 in. (66cm) diameter acrylic plastic dome will be mounted forward and will view 15 degrees down from the horizontal. Viewports will be provided at upper and lower points of sphere. TV mounted externally on pan and tilt device.
Manipulators: Two, jettisonable, 5 ft (1.5m) reach, 50 lbs (23kg) lift.
Lift Point: One circular aperature cut into steel padeye located atop sail.
External Lighting: Five, quartz iodide. Two look downward, two look forward (500 or 1,000 w selectable) and one looks down and aft (250 w).
Fire Extinguisher(s): Two, dry chemical
Sonars: Scanning sonar for search and terrain avoidance. Pinger of variable frequency and pulse rate for surface tracking. Directional antennae for location and "homing" on active sonar beacons. Echo sounder with upward and downward oriented transducers.
Sub-Surface Communications: One underwater telephone
Jettisonable Components: Manipulators, batteries, shot tanks.

System Readiness: DOWB is scheduled to undergo extensive refitting at Southwest Research Institute. This refit will include a one-atmosphere, underwater transfer skirt and a seawater pump buoyancy system, in addition to the features described above. When completed, DOWB will be able to mate with, and operate, a tethered, underwater crawler mechanism with the capabilities of bulldozing and trenching to water depths of 2,000 ft (610m). Operational procedures and ancillary equipment were not available at time of survey.
Classification/Certification: ABS classification will be sought.
Support Ship: Ship of opportunity
Owner: Friendship, SA
Operator: Southwest Research Institute
8500 Culebra Rd.
San Antonio, Tx. 78228
Builder: General Motors Corp.
AC Division
Santa Barbara, Ca.

Point-of-Contact: Mr. Edward Briggs
Southwest Research Institute
(Address same as operator)
Telephone: (512) 684-5111

GLOBULE

CHARACTERISTICS

Length	8.9 ft (2.7m)	Hatch Diameter	NA
Beam	5.9 ft (1.8m)	Life Support Duration	192 man hrs
Height	5.6 ft (1.7m)	Total Power	NA
Draft	NA	Speed: Cruise (kts/hrs)	2/6
Weight (dry)	3 tons (2.7t)	Max (kts/hrs)	NA
Operating Depth	600 ft (182m)	Crew: Pilot(s)	1
Collapse Depth	NA	Observer(s)	1
Launch Date	1973	Payload	552 lbs (250kg)
		Color	NA

Pressure Hull: One steel sphere, 4.6 ft (1.4m) OD
Power Source: Lead acid batteries in pressure-resistant pods, 125 amp-hr
Maneuvering Control: Four motors total. Two, 1.5 hp screw-type, main propulsion motors provide forward/aft movement. Two, 0.75 hp screw-type, vertical thrusters.
Life Support: NA
Viewing: Six dome-shaped viewports, 51cm (20 in.) ID girdle the hull.

Further operational/equipment details unavailable.

System Readiness: Operational; serves as pilot training vehicle and command module for cable burying machine.
Classification/Certification: ABS
Support Ship: NA
Owner: COMEX
13275 Marseille Cedex 2
France
Operator: Same as above
Builder: Same as above
Point-of-Contact: Gerard Chocteau or J.P. Marquinez
c/o COMEX
(Address same as above)
Telephone: 40.11.70 Marseille
Telex: 410985 COMEX MARSL

GRIFFON

CHARACTERISTICS

Length.....7.8m (25.6 ft)	Hatch Diameter.....80cm (31 in.)
Beam.....2.3m (7.5 ft)	Life Support Duration.....120 man hrs
Height.....3.1m (10.2 ft)	Total Power.....26 kWh
Draft.....2.1m (6.9 ft)	Speed: Cruise (kts/hrs)..2/8
Weight (dry).....12.5t (13.7 tons)	Max (kts/hrs).....4/4
Operating Depth..600m (1,969 ft)	Crew: Pilot(s).....2
Collapse Depth...900m (2,953 ft)	Observer(s).....1
Launch Date.....1973	Payload.....350kg (973 lbs)
	Color.....Yellow

Pressure Hull: Cylindrical shape, hemispherical end cap forward, cone aft. Composed of steel 12-14mm (0.3-0.6 in.) thick and OD of 1.6m (5.2 ft).
Power Source: All power (main and emergency) from nickel cadmium batteries. Main battery supply is two banks of 192 cells each supplying 220 VDC of 104 amp-hr capacity. Main batteries are pressure compensated. Auxiliary and emergency batteries are inside hull and supply 28 VDC.
Maneuvering Control: Static: Four MBTs of 2.4m^3 (85 ft^3) capacity total. Two VBTs can change $\pm$ buoyancy by 150 l. (159 qts) each. Dynamic: One, two-speed, stern-mounted, reversible, fixed, screw-type propeller aft of five hp. Two vertical (p/s amidships) thrusters and one lateral (forward) thruster all of 0.5 hp each and all reversible, screw-type.
Pitch/Trim: Transfer of fresh water forward or aft can produce up/down bow angle of $\pm$ seven degrees.
Life Support: Six O_2 flasks of ten l. (ten qts) capacity each are carried externally at 170 bars (2,465 psi). CO_2 is removed by scrubbing through IR8 (soda lime) of which 64kg (141 lbs) are carried. There is an emergency power supply in hull for the scrubber. O_2, CO_2, temperature, humidity and pressure are monitored at opportune periods.
Viewing: Five viewports total, four are in the bow and one is in the conning tower looking forward. Two TV cameras are carried, one monitors forward viewing and another monitors the after area, both are fixed and both have video recorders.
Manipulator: One, 2m (6.6 ft) max. length, electrically-powered, six degrees-of-freedom, parallel jaws-type claw, can lift 15kg (33 lbs) at max. extension and 150kg (331 lbs) in maximum lift position. Max. jaw opening 170mm (6.6 in.), jettisonable.
Lift Points: Two, topside and aft of conning tower. Each consists of an oval-shaped, 7.5cm (3 in.) thick, steel plate which rotates fwd/aft on a steel pin. The attachment point in each plate is a circular hole 60mm (2.4 in.) diameter.
External Lighting: Total lights four, all quartz iodide and 750 w. Three look forward into viewing area; one looks aft to illuminate TV viewing area. French Navy (CERTSM) Mfg.
Surface Lights: One, flashing white, one sec rep. rate, 80cm (32 in.) above surface, operates off emergency battery.
Anchor: A lead clump (jettisonable) of 200kg (442 lbs) weight can be lowered or raised on 20m (66 ft) of cable to act as an anchor.
Fire Extinguishers: Two, distilled water, eight l. (8.4 qts) capacity each.
Emergency Food & Water: Eight liters (8.4 qts) of water taken on each dive. Special life raft type rations are carried in air and water-tight packages.

Medical Supplies: First aid kit.
Surface Communications: One, five channel UHF, 27 mHz, operating off the auxiliary or the emergency (in-hull) battery.
Sub-Surface Communications: One (Straza ATM 504A TIPE Option) operating on 8.0875 kHz with CW.
Sonars: CTFM Sonar (Amtek Straza Mod. 5001B), 360 degree scan. Pinger: One, 14.5 kHz, three to 60 sec. rep. rate. Echo Sounder: Downward looking, 14.5 kHz. Transponders: Two, one responds to and transmits on 25 kHz. The second is interrogated on eight kHz and responds at seven kHz with a three-60 sec. rep. rate.
Marker Buoy: One, attached to after lift point consists of pressure-resistant cylinder, international orange, 80cm (31 in.) length, 40cm (16 in.) diam. and attached by 800m (2,624 ft) of 4mm (0.15 in.) diam. line to a 2m (6.6 ft) long, 15t (18.4 tons) lift capacity cable. The buoy end of the steel cable is configured to accept a retrieving line which can be slid down the nylon line. Lift capacity of buoy is from 10kg (22 lbs) at operational depth, to 40kg (88 lbs) at surface.
Jettisonable Components: Weight - 182kg (401 lbs), manipulator - 239kg (527 lbs), Batteries - 700kg (1,545 lbs), VBT blow - 150kg (331 lbs).
Emergency Breathing: Three, (Fenzy Mfg.), closed-circuit, six hrs duration each.
Communications Procedure: Check with surface every 30 minutes; abort dive if no contact after 45 minutes.

System Readiness: Operational
Classification/Certification: According to French Naval standards
Support Ship: COMMANDANT ROBERT GIRAUD
Owner: French Navy
Operator: Commandant la Division
des Sous-Marins d'Intervention et du Bathyscaphe
du GISMER
83 800 TOULON NAVAL
France
Builder: *Same as above*
Point-of-Contact: Capitaine de Corvette
(Address same as operator)
Telephone: (94) 926300 (Toulon)

HAKUYO

CHARACTERISTICS

Length.....21 ft (6.4m)
Beam.....5.2 ft (1.6m)
Height.....9.5 ft (2.9m)
Draft.....6.2 ft (1.9m)
Weight (dry).....7.2 tons (6.6t)
Operating Depth..984 ft (300m)
Collapse Depth...1969 ft (600m)
Launch Date.....1971

Hatch Diameter.....18 in. (55cm)
Life Support Duration.....156 man hrs
Total Power.....14.4 kWh
Speed: Cruise (kts/hrs)..1/5
Max (kts/hrs).....3.5/1
Crew: Pilot(s).....2
Observer(s).....1
Payload.....331 lbs (150kg)
Color.....Conning tower red; remainder white

Pressure Hull: Steel cylinder with hemispherical end caps, 4.6 ft (1.4m) OD, 12 ft (3.67m) long and 0.47 in. (12mm) to 0.55 in. (14mm) thick in cylinder and end caps, respectively.
Power Source: Lead acid batteries in a pressure-resistant pod delivering 120 V x 100 amp-hr (for six hrs) and 24 V x 100 amp-hr (for six hrs).
Maneuvering Control: Main propulsion (fwd/rev) is provided by a stern-mounted, ten hp, trainable (90 degrees left/right) propeller. Two vertical thrusters, 0.5 hp (fwd/aft); one lateral thruster 0.5 hp (fwd). Static vertical motion derived by two auxiliary VBTs of 9.3 gal (35 l.) and 10.3 gal (39 l.) capacity and one negative tank of 17 gal (65 l.) capacity. VBTs can be blown or pumped dry at operating depth.
Pitch/Trim: Bow angles of ±20 degrees can be obtained by movement of a 253 lb (115kg) weight forward or aft.
Life Support: Thirteen gal (50 l.) of O_2 carried externally. CO_2 removed by baralyme. Monitors for O_2, CO_2 and temperature.
Viewing: A total of 14 viewports 5.9 in. (15cm) ID are located in the bow (18 ea) and in the conning tower (six ea).
Manipulator: One jettisonable manipulator, five degrees-of-freedom, 3.9 ft (1.2m) max. extension, maximum lift of 22 lbs (10kg), parallel jaws type claw with maximum opening of 3.9 in. (10cm).
Lift Points: Main lift point is a specially constructed housing of 23.2 tons (21t) capacity into which a custom made lift device is inserted. Four lift padeyes of 2 in. (5cm) diam. are located topside with a lift capacity of 6.1 tons (5.5t) each.
External Lighting: Three, 1,000 w, incandescent lights (AMF design) are situated on the bow.
Life Jackets: Three, inflatable
Surface Lights: Xenon flashing light 2.5 ft (0.75m) above the water, 48 hrs duration, self-powered, rep. rate: 1/sec.
Fire Extinguisher: One, dry chemical
Surface Communications: CB radio, 27 mHz, 0.1 w, self-powered.
Sub-Surface Communications: One underwater telephone, 8 kHz, powered off either main or emergency batteries. Communications check with surface every 20 minutes, abort dive if no contact within 40 minutes.
Sonars: Obstacle avoidance sonar consists of three bow-mounted, 200 kHz transducers, separated to scan a 60 degree forward cone. Transponder (AMF model) of 10 kHz transmit/receive frequency, self-powered.
Jettisonable Components: Battery pod manually jettisonable to obtain 276 lbs (250kg) positive buoyancy. Manipulator jettisonable. Auxiliary and negative VBTs can be blown or manually pumped dry at operating depth, max. positive buoyancy attainable: 2,336 lbs (1,058kg).

Emergency Breathing: Three scuba regulators draw off flasks of compressed air inside hull providing three hours for each occupant.

System Readiness: Operational
Classification/Certification: Constructed in accordance with Ministry of Transport guidelines.
Support Ship: NEREUS
Owner: Ocean Systems Japan, Ltd.
6-1, Nishishinjuku 2-chome Shinjukuku
Tokyo 160
Japan
Operator: Same as above
Builder: Kawasaki Heavy Industries, Ltd.
2-14 Higashikawasaki-cho
Jyogo-Ku
Kobe 650
Japan
Point-of-Contact: Same as operator
Telephone: 03-344-6401
Cable: Telex No. J26762

JIM

CHARACTERISTICS

Height.....6.5 ft (2.0m)	Life Support.....20 man hrs
Width (front).....3 ft 5 in. (1.0m)	Total Power.....Manual
Width (side).....3 ft 1 in. (0.9m)	Crew: Operator....1
Weight (dry & empty).....910 lbs (413kg)	Payload.....Various to accommodate operator's weight
Weight (dry with operator)..1,100 lbs (499kg)	
Operating Depth.....(See System Readiness)	Color.....White
Launch Date.....1973 (1st unit)	

Pressure Hull: Human configuration. Main body and dome, knee spacer and boots are composed of magnesium alloy. Joints, elbow spacers and hand enclosures composed of an aluminum alloy which are fluid-supported at a pressure in excess of ambient water pressure.
Power Source: Manual
Maneuvering Control: JIM is lowered and raised to the work site by a lift cable. On site the operator is capable of maneuvering as would a human on the surface. The underwater weight can be varied to meet varying conditions.
Life Support: O_2 is carried externally in two flasks of 800 l. (846 qts) total capacity and is bled continuously into the suit. The operator inhales normally and exhales through an oral/nasal breathing mask. A one-atmosphere pressure is automatically maintained by a control valve which supplies O_2 at the rate required to maintain desired pressure. CO_2 is removed by scrubbing (two units) through soda lime. Monitors for O_2, pressure and temperature (inside suit and on surface).
Viewing: Four acrylic plastic viewports in the dome, two look forward obliquely upward and downward; two look obliquely downward and are located to the left and right of the forward-looking viewports. Two smaller viewports in back of dome for rear viewing.
Manipulators: Two arms capable of human arm movement, but restricted to an angular movement of 40 degrees. The arms are an integral part of the pressure suit. The fingers or claws are pincer-type with machined channels to allow various grasping capabilities.
Lift Point: Always operates with lift line attached.
Lighting: NA
Sub-Surface Communications: Hard-wire telephone to surface support craft. Communication line is left open during dive and provides virtually continuous surface-to-diver monitoring.
Jettisonable Components: Cable and ballast weights manually jettisonable. Suit will surface when ballast weights are released.

System Readiness: In April 1976 there were six operational systems rated to working depths of 1,000 ft (305m), 1,250 ft (381m) and 1,500 ft (457m). A 3,000 ft (914m) JIM is currently under development.
Classification/Certification: Lloyds Register of Shipping
Support Ship: Ship of Opportunity
Owner: DHB Construction Ltd.
Operator: DHB Construction Ltd.
Alton, England

Builder: Underwater Marine Equipment Ltd.
Farnborough, Hants
England

Point-of-Contact: (United States)
Oceaneering International
10575 Katy Freeway
Houston, Tx. 77024
Telephone: (713) 461-4477
Telex: 775181
Cable: OCEANEERNG

JOHNSON-SEA-LINK I

CHARACTERISTICS

Length.....22.8 ft (6.9m)	Hatch Diameter.....18 in. (46cm) (Pilot)
Beam.....7.9 ft (2.4m)	Hatch Diameter.....27 in. (69cm) (LOC)
Height.....10.6 ft (3.2m)	Life Support Duration.....480 man hrs
Draft.....7.5 ft (2.3m)	Total Power.....32 kWh
Weight (dry).....11 3/4 tons (10.7t)	Speed: Cruise (kts/hrs)..0.75/6
Operating Depth..1,000 ft (305m)	Max (kts/hrs).....1.25/
Collapse Depth...8,000 ft (2,348m)	Crew: Pilot(s).....1
Launch Date.....1971	Observer(s).....3 (2 divers)
	Payload.....1,000 lbs (453kg)
	Color.....Aluminum

Pressure Hull: Two hulls: one sphere (fwd) and one cylinder (aft). Sphere: acrylic plastic, 66 in. (168cm) OD, 4 in. (10cm) thick. Cylinder: aluminum, 59.5 in. (151cm) OD, 8 ft (2.4m) long, 3.36 in. (8.5cm) thick.
Power Source: Fourteen, two VDC Exide DT6-33 pressure-compensated, lead acid batteries rated at 1,152 amp-hrs. Two aircraft-type emergency batteries, each provides 20 amp-hr at 20 hr rate.
Maneuvering Control: Dynamic: Eight, four-bladed propellers 1.25 hp each, continuously variable, reversible. Three on stern trainable 90 degrees p/s; two additional (fwd/aft) fixed, p/s forward thrusters, two vertical thrusters, two lateral thrusters (fwd/aft). Static: Two VBTs 88 lbs (40kg) capacity each. Two dive ballast tanks of 201 lbs (91kg) capacity each. Two MBTs of 1727.5 lbs (782kg) capacity each.
Life Support: Two external O_2 tanks of 267 ft^3 (7.6m^3) capacity each at 2400 psi (168kg/cm^2). Three (one sphere, two cylinders) mixed gas cylinders of 1,769 ft^3 (50.1m^3) (sphere) and 614.5 ft^3 (17.4m^3) (cylinder) capacity each. CO_2 scrubber compound: LiOH, 50 lbs (23kg) spare carried in both compartments, 6 lbs (2.7kg) soda sorb used to perform routine mission. Two CO_2 monitors each in pilot's and diver's compartments. Two O_2 monitors in pilot's sphere, one in diver's compartment. Diver life support, when locked out, is from a Bio-Marine CCR-1000 which can also be used as backup CO_2 scrubber. Pilot's sphere contains a 0-5 psi (0.35kg/cm^2) pressure sensor and an air conditioner. Protective clothing (thermal) carried.
Viewing: Pilot's sphere: Panoramic viewing. Dive cylinder: one viewport each side, one forward, one in both hatch covers.
Manipulator: One three-degrees-of-freedom, variable claws (scissors, parallel jaws, clam shell), 82 in. (208cm) maximum extension, 50 lbs (23kg) maximum weight lift (scissors grip). Not jettisonable.
Lift Point: A rectangular housing, 8.6 in. (21.8cm) x 8.6 in. x 16.9 in. (43cm) is situated topside, amidships. A torpedo-shaped device (Drop Lock) with four flukes fits into the housing and the flukes provide the lift point when tension is applied to the lift cable. To release the device, the cable is relaxed and high pressure air is blown into the housing by the pilot. The air blows the flukes back against the core and allows it to be pulled free by the surface.
External Lighting: Four lights total, all incandescent (Birns & Sawyer Mod. 5535) two are mounted forward (p/s) on both ballast tanks (350 w). One (250 w) is mounted on a vertically-rotating plate just forward of the pilot's sphere.
Life Jackets: Four, inflatable
Distress Flares: Six, red, fired through pilot's hatch cover.
Surface Lights: White, flashing xenon light, self-powered, with a duration of 40 hrs and a flash of 1.2 watt-seconds intensity every two seconds. Height above surface about 1 ft (0.3m).
Fire Extinguisher: One, dry chemical, in each compartment.

Emergency Food & Water: Two gal (7.5 l.) of water and two sea water desalinization kits in each compartment. Emergency food: raisins, Hershey Bars, canned nuts, fruit juice.
Medical Supplies: First aid kit in both compartments
Surface Communications: Primary: FM transceiver (Motorola Mocom 35), 15 w output and two frequencies, one for sub-to-ship and one for Coast Guard (156.8 mHz). Secondary: FM transceiver (Motorola Handie-Talkie), five w output, self-powered with eight hrs duration at five % transmit, five % receive and 90% standby. Frequencies of secondary same as primary.
Sub-Surface Communications: Sub-to-ship: Underwater telephone (Ametek/Straza Mod. Atm-504A) frequency 8.087 kHz, CW, 20,000 yds (6,096m) max range. This model can also act as a transponder (transmit 9.337 kHz), a pinger (transmit 14.5 kHz) and an echo sounder (transmit; receive at 14.5 kHz). Sub-to-diver: 1) Underwater telephone (Helle Intercom), 300-1,200 Hz, with speaker/microphone in both pilot sphere and LOC. 2) One-way communication (sub-to-diver) is provided by an external speaker and amplifier transmitting on 200 to 5,000 Hz. Inter compartment: A sound-powered phone provides voice communication between the pilot's sphere and LOC.
Sonars: Scanning sonar (Straza Model 500 CTFM), transmits from 87-72 kHz, scans 360 degrees at ranges from 3 yds (0.9m) to 1,500 yds (457m). Transponder interrogating at 82-87 kHz, receiving at 40 to 55 kHz. Displays visually and aurally. Pingers: Two, one (Ametek Straza Mod. 7050A) is self-powered, 25 day duration, dual frequency (9 & 45 kHz), salt water-activated, rep. rate of 1.5 sec. The second (Helle Mod. 2460) is powered by the submersible's battery, is pilot-activated and transmits at 37 kHz once/second, duration considered indefinite. Transponders: One (Vicker's model) receiving at 39 kHz replying at 178 kHz, powered by submersible's batteries.
Marker Buoys: A 4.4 ft^3 (0.12m^3) spherical, fluorescent pink, polyfoam, inflatable buoy containing one quart of mineral oil is held within an aluminum tunnel behind the pilot's sphere (starboard). High pressure air is introduced by the pilot and the buoy expands and floats to the surface with 281 lbs (127kg) positive buoyancy. The buoy unreels 2,000 ft (610m) of 3/16 in. (0.5cm) diam. Phillystran line as it ascends. A specially designed drop lock can be slid down the cable to engage with a lift housing for retrieval.
Jettisonable Components: Battery pod jettisonable - 2,178 lbs (987kg). VBTs and MBTs can be blown at operating depth 3,455 lbs (1,565kg).
Emergency Breathing: Compressed air (from MBT) or mixed gas can be used in pilot's sphere and LOC by use of emergency breathing regulators (two each with facemasks in each compartment).
Egress Procedures: Pilot and observer can enter dive compartment and bring vehicle to surface.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: R/V JOHNSON
Owner: Harbor Branch Foundation, Inc.
Rt. #1, Box 196
Ft. Pierce, Florida 33450
Operator: Same as above
Builder: Same as above
Point-of-Contact: Mr. Roger W. Cook
Harbor Branch Foundation, Inc.
(Address same as above)
Telephone: (305) 465-2400

JOHNSON-SEA-LINK II

CHARACTERISTICS

Length	22.8 ft (6.9m)
Beam	7.9 ft (2.4m)
Height	10.6 ft (3.2m)
Draft	7.5 ft (2.3m)
Weight (dry)	11 3/4 tons (10.7t)
Operating Depth	1,000 ft (305m)
Collapse Depth	6,000 ft (1,829m)
Launch Date	1971
Hatch Diameter	18 in. (46cm) (Pilot) 27 in. (69cm) (LOC)
Life Support Duration	480 man hrs
Total Power	32 kWh
Speed: Cruise (kts/hrs)	0.75/6
Max (kts/hrs)	1.25/NA
Crew: Pilot(s)	1
Observer(s)	3 (2 divers)
Payload	1,000 lbs (453kg)
Color	Aluminum

Pressure Hull: Two hulls: one sphere (fwd) and one cylinder (aft). Sphere: acrylic plastic 66 in. (168cm) OD, 4 in. (10cm) thick. Cylinder: Aluminum, 59.5 in. (151cm) OD, 8 ft (2.4m) long, 3.36 in. (8.5cm) thick.

Power Source: Fourteen, two VDC, Exide DT6-33, pressure compensated, lead acid batteries rated at 1,152 amp-hrs at six hr rate. Two aircraft-type emergency batteries, each provides 24 amp-hr at 20 hr rate.

Maneuvering Control: Dynamic: Eight, four-bladed propellers, 1.25 hp each, continuously variable, reversible. Three on stern trainable 90 degrees p/s; two additional which are mounted p/s amidships; two vertical thrusters (fwd/aft), two lateral thrusters (fwd/aft). Static: Four VBTs 334 lbs (151kg) capacity total. Two dive ballast tanks of 210 lbs (95kg) capacity each. Two MBTs of 1,865 lbs (845kg) total capacity.

Life Support: Two external O_2 tanks of 330 ft^3 (9.4m^3) capacity each at 2600 psi (182kg/cm^2). Six (one sphere, five cylinders) mixed gas cylinders of 1,769 ft^3 (50m^3) (sphere) and 1,425 ft^3 (100m^3) (cylinders) capacity each at 2600 psi. CO_2 scrubber compound: LiOH, 50 lbs (23kg) spare carried in both compartments, 6 lbs (2.7kg) soda sorb to perform routine mission. Two CO_2 monitors each in pilot's sphere and LOC. Two O_2 monitors in pilot's sphere, one in LOC. Diver life support, when lock out, is from a Bio-Marine CCR-1000 which can also be used as backup CO_2 scrubber, emergency life support is built into this system. Pilot's sphere contains a 0-5 psi (0.35kg/cm^2) pressure sensor and an air conditioner. Protective clothing carried.

Viewing: Pilot's sphere: panoramic viewing. LOC: one viewport each side, one forward, one in both hatch covers.

Manipulator: One, three degrees-of-freedom, variable grips (scissors, parallel jaws, clam shell), 82 in. (208cm) maximum extension, 50 lbs (23kg) maximum weight lift (scissors grip). Not jettisonable.

Lift Point: A rectangular housing, 8.6 in. (21.8cm) x 8.6 in. x 16.9 in. (43cm) is situated topside, amidships. A torpedo-shaped device (Drop Lock) with four flukes fits into the housing and the flukes provide the lift point when tension is applied to the lift cable. To release the device, the cable is relaxed and high pressure air is blown into the housing by the pilot. The air blows the flukes back against the core and allows it to be pulled free.

External Lighting: Four lights total, all incandescent (Birns & Sawyer Mod. 5535) two are mounted forward (p/s) on both ballast tanks (350 w). One (250 w) is mounted on a vertically-rotating plate just forward of the pilot's sphere.

Life Jackets: Four, inflatable

Distress Flares: Six, red, fired through pilot's hatch cover.

Surface Lights: White, flashing xenon light, self-powered, with a duration of 40 hrs and a flash of 1.2 watt-seconds intensity every two seconds. Height above surface about 1 ft (0.3m).

Fire Extinguisher: One, dry chemical in each compartment.

Emergency Food & Water: Two gal (7.5 l.) of water and two sea water desalinization kits in each compartment. Emergency food: raisins, Hershey Bars, canned nuts, fruit juice.
Medical Supplies: First aid kit in both compartments
Surface Communications: Primary: FM transceiver (Motorola D-43-DEN), 15 w output and two frequencies, one for sub-to-ship and one for Coast Guard (156.8 mHz). Secondary: FM transceiver (Motorola Handi-Talkie), 5 w output, self-powered with eight hrs duration at five % transmit, five % receive and 90% standby. Frequencies of secondary same as primary.
Sub-Surface Communications: Sub-to-ship: Underwater telephone (Ametek/Straza Mod. Atm-504A), frequency 8.087 kHz, CW, 20,000 yds (6,096m) max range. This model can also act as a transponder (transmit 9.337 kHz; receive 10.087 kHz), a transponder interrogater (transmit 10.087 kHz, receive 9.337 kHz), a pinger (transmit 14.5 kHz) and an echo sounder (transmit; receive at 14.5 kHz). Sub-to-diver: 1) underwater telephone (Helle Intercom), 300-1,200 Hz, with speaker/microphone in both pilot's sphere and LOC. 2) One-way communication (sub-to-diver) is provided by an external speaker and amplifier transmitting on 200 to 5,000 Hz. Inter compartment: A sound-powered phone provides voice communication between the pilot's sphere and dive compartment.
Sonars: Scanning sonar (Straza Model 500 CTFM), transmits from 87 to 72 kHz, scans 360 degrees at ranges from 3 yds (0.9m) to 1,500 yds (457m). Transponder interrogating at 82-87 kHz, receiving at 40 to 55 kHz. Displays visually and aurally. Pingers: Two, one (Ametek Straza Mod. 7050A) is self-powered, 25 day duration, dual frequency (9 & 45 kHz), salt water-activated, rep rate of 1.5 sec. The second (Helle Mod. 2460) is powered by the submersible's battery, is pilot-activated and transmits at 37 kHz once every second, duration considered indefinite. Transponders: One (Vicker's model) receiving at 39 kHz replying at 178 kHz, powered by submersible's batteries.
Marker Buoys: A 4.4 ft^3 (0.12m^3) spherical, fluorescent pink, polyfoam inflatable buoy containing one quart of mineral oil is held within an aluminum tunnel behind the pilot's sphere (starboard). High pressure air is introduced by the pilot and the buoy expands and floats to the surface with 281 lbs (127kg) positive buoyancy. The buoy unreels 2,000 ft (610m) of 3/16 in. (0.5cm) diam. Phillystran line as it ascends. A specially designed drop lock can be slid down the cable on 1,500 ft (457m) of cable to engage with a lift housing for retrieval of the submersible.
Jettisonable Components: Battery pod, jettisonable - 2,178 lbs (987kg). VBTs and MBTs can be blown at operating depth 3,455 lbs (1,565kg).
Emergency Breathing: Compressed air (from MBT) or mixed gas can be used in pilot's and diver's compartments by use of emergency breathing regulators (two each with facemasks in each compartment).
Egress Procedure: Pilot and observer can enter dive compartment and bring vehicle to surface.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: R/V SEA DIVER
Owner: Harbor Branch Foundation, Inc.
Rt. #1, Box 196
Ft. Pierce, Florida 33450
Operator: Same as above
Builder: Same as above
Point-of-Contact: Mr Roger W. Cook
(Address same as above)
Telephone: (305) 465-2400

LEO I

CHARACTERISTICS

Length	20 ft (6.1m)
Beam	10 ft (3.1m)
Height	8 ft (2.4m)
Draft	8.75 ft (2.67m)
Weight (dry)	11.5 tons (10.4t)
Operating Depth	2,000 ft (610m)
Collapse Depth	4,200 ft (1,280m)
Launch Date	1976
Hatch Diameter	19.4 in. (49.5cm)
Life Support Duration	340 man hrs
Total Power	40.8 kWh
Speed: Cruise (kts/hrs)	NA
Max (kts/hrs)	2/NA
Crew: Pilot(s)	1
Observer(s)	2
Payload	1,450 lbs (657kg)
Color	White, orange sail

Pressure Hull: Spherical shape 80 in. (203cm) OD and 1.0 in. (2.54cm) thick composed of A516 Grade 70 steel.
Power Source: Lead acid batteries, pressure-compensated provide 120 VDC for 310 amp-hrs and 24 VDC for 150 amp-hrs.
Maneuvering Control: Two reversible, five hp (each) thrusters mounted p/s amidships can be rotated 120 degrees in the vertical plane to provide horizontal or vertical thrust.
Pitch/Trim: Sea water may be pumped from an aft sphere to a tank in the pressure hull to provide approximately ±20 degrees bow angle. Approximately 400 lbs (180kg) of water is normally carried in the tanks. Lead trays carrying up to 900 lbs (408kg) of lead can be adjusted to varying payload conditions.
Life Support: O_2 is carried inside and outside of the pressure hull and totals 324 SCF ($9.1m^3$). CO_2 is removed by LiOH. Monitors for O_2, CO_2, temperature, humidity and pressure.
Viewing: Plastic bow dome 4 in. (10.2cm) thick and 33 in. (84cm) outside radius.
Manipulator: One, hydraulically-powered, six degrees-of-freedom, scissors type claw, 66 in. (168cm) total length, 240 lbs (104kg) lift capacity at full extension. Claw jettisonable.
Lift Point: Single point lift; configuration not yet available.
External Lighting: Two, 1,000 w each quartz iodide lights mounted on the bow.
Life Jackets: Three, inflatable
Surface Lights: One, flashing white
Fire Extinguishers: One, dry chemical
Medical Supplies: First aid kit
Emergency Food and Water: Life boat type provisions and water
Surface Communications: One VHF transceiver
Sub-Surface Communications: One underwater telephone (Sub Comm Mfg.), 9 and 27 kHz, transducers on top and bottom of vehicle. Can be used as a pinger on 27 kHz.
Surface Homing Devices: Radio beacon
Sonars: Scanning sonar (Wesmar SS140S), 160 kHz, 1,600 ft (488m) max. range, 360 degree scan, CRT display, transducer tiltable + four degrees to -90 degrees from the horizontal. Pinger mode in underwater telephone.
Directional Antennae: One hydrophone receiving on 27 kHz.
Jettisonable Components: Lead weight of 375 lbs (170kg) is manually jettisonable. Thrusters and manipulator claws.
Emergency Breathing: Four closed-circuit (Drager Mfg.) devices, each provides 45 minutes breathing duration.

System Readiness: Under construction, scheduled completion is for July 1976
Classification/Certification: ABS
Support Ship: NA
Owner: P&O Subsea (UK), Ltd.
Liscarton House
127 Sloane Street
London
England
Operator: P&O Subsea (UK), Ltd.
P.O. Box 97
Dents Wharf
Depot Rd.
Middlesbrough, Cleveland
England
Builder: International Hydrodynamics, Ltd.
Vancouver, B.C.
Canada
Point-of-Contact: Robert Eastaugh, Gen. Mgr.
Address same as operator
Telephone: Middlesbrough 41441
Telex: 587124

MERMAID II

CHARACTERISTICS

Length.....17.9 ft (5.5m)	Hatch Diameter.....20.5 in. (52.1cm)
Beam.....5.6 ft (1.7m)	Life Support Duration.....240 man hrs
Height.....8.5 ft (2.6m)	Total Power.....18.5 kWh
Draft.....5.9 ft (1.8m)	Speed: Cruise (kts/hrs)...1.5/8
Weight (dry).....6.55 tons (5,934kg)	Max (kts/hrs).....3/NA
Operating Depth.....1,000 ft (305m)	Crew: Pilot(s).....1
Collapse Depth.....1,920 ft (585m)	Observer(s).....1
Launch Date.....1972	Payload.....450 lbs (204kg)
	Color.....White with orange MBTs

Pressure Hull: Cylindrical shape, high tensile steel (St53.7), 4.1 ft (1.25m) diam., 14.1 ft (4.3m) length, cylindrical conning tower and plastic bow dome.
Power Source: Lead acid batteries in pressure resistant pods, 56 V, 330 amp-hr. Emergency power in hull, 40 amp-hr, 24 V, will power all electrical components except propulsion.
Maneuvering Control: Main propulsion: stern-mounted, reversible propeller 90 degrees trainable left/right, three hp. One lateral thruster, 1.6 hp, trainable 90 degrees in the horizontal (from p/s to fwd-aft) on the upper bow guard. Two vertical thrusters mounted p/s amidships.
Pitch/Trim: Batteries moved forward/aft in pod can provide $\pm$15 degrees bow angle.
Life Support: Four, external O_2 flasks. LiOH is used to remove CO_2. Monitors for O_2, CO_2, temperature, humidity and pressure. Drager hand analyzer used for backup O_2 but is primary means of CO_2 monitoring. CO_2 monitored every 30 minutes.
Viewing: Bow dome 36 in. (91cm) diam. TV camera with recorder on pan/tilt mechanism forward. Eight small viewports in conning tower; one is in hatch cover.
Manipulator: One, five degrees-of-freedom, hydraulically-activated, scissors claw. Linear extension. Total length 7 ft 10 in. (2.4m). Grasping capacity 100 lbs (45kg). Not jettisonable.
Lift Point: One, aft of sail. Opening is rectangular, 4.75 in. (12.1cm) wide, 12 in. (30.5cm) long, 3 in. (7.6cm) thick and trends athwartship.
External Lighting: Six lights total. Five are directed forward; three 75 w incandescent, one thallium iodide 50 w, two 70 w incandescent. One 75 w light mounted topside is directed towards the stern. Strobe lights (3 ea.).
Life Jackets: Two inflatable with closed-circuit breathing, (Drager Manuf.), 30 minutes each duration, mixed gas at 3,000 psi with soda sorb scrubber.
Surface Lights: One flashing, white light powered by normal or emergency system. Rep. rate is variable. Height about 3 ft (0.9m) above water.
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Dry rations and two gals (2 l.) of water.
Medical Supplies: First aid kit
Surface Communications: CB
Sub-Surface Communications: Underwater telephone (Hydro Products Mod. DV812 and Mod. S812), 8.0875 kHz, CW. Operates off both normal and emergency power. Communications check every 15 minutes; if no contact in 30 minutes, dive is aborted.

Sonars: Scanning Sonar (Wesmar Mod. SS140S), 160 kHz, includes transponder interrogation. Pingers: Four total, two at 45 kHz, salt water activated (Johnson Laboratories, Mod. 38/330 and 38/331) 1 pulse/sec with CW capability; two are 37 kHz (Helle Mod. PC06). Two are mounted topside and two on keel. Keel pingers will be used as backup to locate submersible if lost in fog on the surface.
Marker Buoy: One, manually (hydraulically) released with 1,500 ft (457m) of line, orange color, football shape, 18 in. (46cm) length, 12 in. (30.5cm) width.
Jettisonable Components: Manually droppable weight 500 lbs (227kg). Air blow of MBTs.
Emergency Breathing: Closed-circuit breathing from two Drager units provide 30 minutes for each occupant. Scuba regulators (two each) draw off compressed air.
Egress Procedure: Flood hull and ascend to surface with Drager life jacket/closed-circuit breathing device.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: NA
Owner: IUC International Inc.
Apartado Postal 1450
Panama 1, Panama
Operator: International Underwater Contractors
P.O. Box 95
City Island, N.Y. 10464
Builder: Bruker-Physik AG
Karlsruhe, West Germany
Point-of-Contact: Mr. Booker T. Washington
264 Fordham Place
City Island, New York 10464
Telephone: (212) 885-0600
Cable: TECHDIVER

MERMAID III & IV

CHARACTERISTICS

Length	7.2m (23.6 ft)	Hatch Diameter	60cm (23.6 in.)
Beam	1.8m (5.9 ft)	Life Support Duration	160 man hrs
Height	2.7m (8.8 ft)	Total Power	36 kWh
Draft	2.0m (6.6 ft)	Speed: Cruise (kts/hrs)	1.5/7.5
Weight (dry)	11.5t (12.6 tons)	Max (kts/hrs)	2.8/2.5
Operating Depth	260m (853 ft)	Crew: Pilot(s)	1
Collapse Depth	450m (1,476 ft)	Observer(s)	2
Launch Date	1975 (III)	Payload	150kg (331 lbs)
	1976 (IV)	Color	Sail and fairings are orange, remainder is light gray

Pressure Hull: Cylindrical shape with hemispherical end caps, composed of ST E 43 steel, ID 125cm (49.2 in.); length 630cm (248 in.).
Power Source: Lead acid batteries in two pressure-resistant pods, 56 cells, 330 amp-hr/cell, 110 V.
Maneuvering Control: Dynamic: Stern screw-type propeller, ten hp, reversible and trainable 90 degrees p/s. Two vertical (p/s) and two lateral (fwd/aft) thrusters of 1.5 hp each. Static: MBT ±960kg (2,119 lbs) and anchor for lockout operations provide vertical movement.
Pitch/Trim: Batteries may be hydraulically shifted forward or aft to obtain a trimming moment of ±160 mkp.
Life Support: O_2 and H_e carried externally. One CO_2 scrubber in pilot's sphere and LOC, scrubber in LOC is heated. Scrubbing compound is Drager-Atemkalk, emergency power for scrubber (24 V, 36 amp/hr). Monitoring devices for O_2 and CO_2.
Viewing: Plastic bow dome of 110cm (43.3 in.) diam., five 17cm (6.7 in.) diam. and two 8cm (3.1 in.) diam. viewports in conning tower. Four 17cm diam. viewports in LOC.
Lift Point: Main lift point aft of conning tower. It is fishhook-like in shape and inverted with the hook or barb side pointing aft. The hook is 10.1cm (4 in.) wide, 7.6cm (3 in.) thick and has a minimal opening of 7.6cm (3 in.). A safety bar is slid across the hook opening to secure the lift hauser in place.
External Lighting: Two, 30 w, quartz iodide lights on bow (Bruker Mfg.).
Surface Lights: One, 100 w, flashing light, white, 90cm (35 in.) above surface.
Anchor: An anchor is carried to hold vehicle on the bottom during lockout operations. It weighs 250kg (551 lbs) and is attached to a 3m (9.8 ft) long anchor line.
Fire Extinguisher: One, dry chemical
Automatic Deballasting: Main ballast tanks will be blown dry automatically if vehicle descends below operational depth.
Surface Communications: One, radio transceiver, 27.12 mHz.
Marker Buoys: One, (planned) manually (hydraulically) released with sound-powered telephone on a cable of undetermined length. Orange color. Football shaped. Length 46cm (18 in.), width (diam. 30.5cm (12 in.).
Jettisonable Components: Anchor - 250kg (551 lbs). MBT blow - 960kg (3,149 lbs).
Emergency Breathing: Three, scuba regulators and mouthpieces draw off deballasting air. Duration depends on capacity of tanks, which is $100m^3$ ($3,531 ft^3$) under normal operating conditions.

Egress Procedure: Pilot's compartment can be flooded to egress through conning tower hatch. Crew can enter diving (lockout) chamber, pressurize to ambient, and egress through lockout hatch.

System Readiness: Both under construction. MERMAID III will be delivered to P&O Subsea in April, 1976, IV will be completed soon thereafter.
Classification/Certification: ABS & GERMANISCHER Lloyds
Support Ship: SUBSEA I
Owner: III - P&O Subsea (See PC-9)
IV - Bruker-Physik AG
D-7512 Karlsruhe - Rheinsteffen
Silberstreifen
West Germany
Operator: Same as above
Builder: Bruker-Physik AG
(Address same as above)
Point-of-Contact: Dipl. Ing. Jorg Haas
c/o Bruker-Physik AG
(Address same as above)
Telephone: (0721) 51185
Telex: (07) 826-836

MOANA I

CHARACTERISTICS

Length	3.7m (12.2 ft)	Hatch Diameter	55cm (21.6 in.)
Beam	2.28m (7.5 ft)	Life Support Duration	288 man hrs
Height	2.62m (8.6 ft)	Total Power	32.4 kWh
Draft	2.20m (7.2 ft)	Speed: Cruise (kts/hrs)	2/5
Weight (dry)	7t (7.7 tons)	Max (kts/hrs)	3.2/NA
Operating Depth	400m (1,312 ft)	Crew: Pilot(s)	2
Collapse Depth	700m (2,296 ft)	Observer(s)	1
Launch Date	1974	Payload	100kg (220 lbs)
		Color	Gray: framework & hull Orange & white: sail

Pressure Hull: Two steel spheres, ID 1.4m (4.6 ft) joined by a steel cylinder ID 55cm (1.8 in.) and 25cm (10 in.) length.
Power Source: Lead acid batteries in pressure-resistant cylinders. Batteries deliver 120 V at 270 amp-hr and 24 V at 65 amp-hr. Internal batteries for emergency power provide 24 V at 15 amp-hr.
Maneuvering Control: Eight, fixed, reversible screw-type propellers. Four provide main forward propulsion, two are vertical and two are lateral thrusters. All are 1.5 hp.
Pitch/Trim: Two hard tanks of 40 l. (10.6 gal) capacity each provide ±15 degrees bow angle by differential filling of the tanks.
Life Support: O_2 is carried externally in two tanks of 25 l. (6.6 gal) capacity each at 200 bars (2,900 psi). CO_2 is removed by scrubbing through soda lime of which 70kg (154 lbs) is carried on each dive. The CO_2 scrubbers (one in each sphere) have emergency power inside the pressure hull. Monitors for O_2, CO_2, temperature, humidity and pressure which are checked every 15 minutes. Electric heaters are also carried.
Viewing: Nine viewports total. Eight of 55cm (21.6 in.) diam. each are in the forward sphere, five girdle the hull equator, one in the hatch, one looks up and forward, one looks down and forward. After sphere has one 30cm (11.8 in.) diam. viewport which looks directly aft. TV and recorder carried internally.
Manipulator: One, electrically-driven, six degrees-of-freedom, jettisonable, 1.8m (5.9 ft) long with parallel jaws-type claw. The manipulator can lift 35kg (72.2 lbs) at maximum extension; the claw can apply 150kg (331 lbs) of pressure.
Lift Points: A 1.25 in. (3.2cm) thick, 8.3cm (3.25 in.) ID shackle is mounted topside and aft of the hatch. A 3.2cm (1.25 in.) thick cable is attached to the shackle to form a loop approximately 0.9m (3 ft) long.
External Lighting: Eleven lights total, all quartz iodide and all 300 w each. Distribution is as follows: three forward, three starboard, three port and two are security lights illuminating lift attachment.
Life Jackets: Three, inflatable
Radar Reflector: One permanently mounted, 1.5m (4.9 ft), above water surface.
Surface Lights: One red and one green running light. One flashing, self-powered, white light, rep rate once every two seconds, 50cm (20 in.) above water surface.
Fire Extinguisher: One, dry chemical
Emergency Food and Water: Equal to life support duration.

Surface Communications: VHF, (Svenska Mod. ME-60) multi-channel transceiver, 25 w power. Emergency and identification communications on channel 16 (156-180 mHz), five channels for normal communications 10 km (5.4 nm) range.
Sub-Surface Communications: One underwater telephone (TSM 5110), 8.08 kHz, 100 w, CW, operates off both main batteries and emergency power.
Surface Homing Devices: Radio beacon, self-powered, pilot-activated, standard distress frequency (156.8 mHz). (A feature of the surface communications transceiver.)
Sonars: Scanning Sonar: (Wesmar SS140S) 150 kHz, 1,600 ft (500m) range, 360 degree scan, CRT display, beam width seven degrees, transducer tilt adjustable from the horizontal four degrees upward to 90 degrees downward. Echo Sounder: (Koden Mod. 385A) 75 kHz, three transducers (looking up, forward, down) maximum range: 300m (984 ft), strip chart recorder. Transponder: receives on 25 kHz, transmits on 50 kHz.
Marker Buoys: Three, two small and one large. Small buoys are ejected from the vehicle and consist of a small diameter nylon line, a three kg (6.6 lb) anchor weight and a 15cm (6 in.) diam. sphere. Large buoy is a rectangular block of syntactic foam 1.2m x 1.2m x 0.4m (3.9 ft x 3.9 ft x 1.3 ft), with 150kg (331 lbs) lift, international orange with white stripes on edges, and is mechanically released. It is attached to vehicle by 400m (1,312 ft) of electrical cable which serves as a hardwire telephone.
Jettisonable Components: Security weight - 140kg (309 lbs), four propellers - 120kg (264 lbs), battery pods - 770kg (1,699 lbs), manipulator - 130kg (287 lbs). Total jettisonable weight (wet) - 1,600kg (2,560 lbs). Ballast tanks can be blown at operational depth to provide 500kg (1,103 lbs) positive buoyancy.
Emergency Breathing: Three (Fenzy Mfg.), providing four hours for each occupant.
Communications Procedure: Check with surface every 15 minutes, abort dive if no contact with 30 minutes.

System Readiness: Operational
Classification/Certification: ABS and Veritas
Support Ship: ANGUILLE (a barge which is moored for near-shore operations)
Owner: COMEX
13275 Marseille Cedex 2
France
Operator: Same as above
Builder: Same as above
Point-of-Contact: Gerard Chocteau or J.P. Marquinez
c/o COMEX
Address same as above
Telephone: 40.11.70 Marseille
Telex: 410985 COMEX MARSL

MOANA III, IV, V

CHARACTERISTICS

Length	4.37m (14.4 ft)	Hatch Diameter	55cm (21.6 in.)
Beam	2.48m (8.1 ft)	Life Support Duration	288 man hrs
Height	2.44m (8.0 ft)	Total Power	45.6 kWh
Draft	1.73m (5.7 ft)	Speed: Cruise (kts/hrs)	1/12
Weight (dry)	9t (9.9 tons)	Max (kts/hrs)	2.5/3
Operating Depth	400m (1,312 ft)	Crew: Pilot(s)	2
Collapse Depth	800m (2,624 ft)	Observer(s)	1
Launch Date	1976	Payload	362kg (800 lbs)
		Color	Gray: Framework White: Hull & sail

Pressure Hull: Two steel spheres 1.7m (5.6 ft) OD, 14mm (0.55 in.) thick, joined by a steel cylinder 73cm (28.7 in.) ID and 40cm (15.7 in.) long.
Power Source: Main power from lead acid batteries in pressure-resistant cylinders providing 120 V at 380 amp-hr and 24 V at 180 amp-hr. Emergency power inside pressure hull provides 24 V at 15 amp-hr.
Maneuvering Control: Eight, fixed, reversible, screw-type propellers. Four provide main forward propulsion, two are vertical and two are lateral thrusters. All are 2.5 hp.
Pitch/Trim: Battery shifting inside cylinders provide ±30 degrees bow angle.
Life Support: O_2 is carried externally in two flasks, each have a volume of 25 l. (0.9 ft^3) and are filled to 200 bars (2,900 psi) pressure. CO_2 is removed by two scrubbers filled with soda lime, 65.5kg (145 lbs) is carried. The scrubbers can operate off the main and emergency batteries. Monitors for O_2, CO_2, temperature, humidity and pressure which are checked very 15 minutes. Electrical heaters are included.
Viewing: Nine viewports total. Eight of 55cm (21.6 in.) diam. each are in the forward sphere, five girdle the hull equator, one is in the hatch, one looks up and forward, one looks down and forward. After sphere has a viewport of 69cm (27.2 in.) diam. in the hatch cover. TV and recorder carried internally.
Manipulator: One, electrically-driven, six degrees-of-freedom, jettisonable, 1.8m (5.9 ft) long with parallel jaws-type claw. The manipulator can lift 35kg (77.2 lbs) at maximum extension; the claw can apply 150kg (331 lbs) of pressure.
Lift Points: Circular-shaped, steel ring mounted topside, amidships, 28cm (11 in.) ID, 30t (33 tons) lift capacity.
External Lighting: Eleven lights total, all quartz iodide and all 300 w each. Three look forward, three starboard, three port and two are security lights for illuminating lift attachments.
Life Jackets: Three, inflatable
Distress Rockets: Two
Radar Reflector: One, permanently-mounted, diamond-shaped, 1.5m (4.9 ft) above water surface.
Surface Lights: One, red and one green light. One flashing white light, rep. rate once every two seconds.
Fire Extinguisher: One, dry chemical
Emergency Food and Water: Equal to life support duration
Surface Communications: VHF, (Svenska Mod. ME-60) multi-channel transceiver, 25 w power. Emergency and identification communications on channel 16 (156.80 mHz), five channels for normal communications 10 km (5.4 nm) range.

Sub-Surface Communications: One underwater telephone (TSM 5110), 8.083 kHz, 100 w power, CW, operates off main and emergency batteries.
Surface Homing Devices: Radio beacon, self-powered, pilot-activated, standard distress frequency (156.8 mHz). (A feature of the surface communications transceiver)
Sonars: Scanning Sonar: (Wesmar SS140S), 160 kHz, 1,600 ft (500m) range, 360 degree scan, CRT display, beam width seven degrees, transducer tilt adjustable from the horizontal four degrees upward to 90 degrees downward. Echo Sounder: (Koden Mod. 385A) 75 kHz, three transducers (looking up, forward, down), maximum range: 300m (984 ft), strip chart recorder.
Marker Buoys: Three, two small and one large. Small buoys are ejected from the vehicle and consist of a small diameter nylon line, a three kg (6.6 lbs) anchor weight and a 15cm (6 in.) diam. sphere. Large buoy is a rectangular block of syntactic foam 1.2m x 1.2m x 0.4m (3.9 ft x 3.9 ft x 1.3 ft), with 150kg (331 lbs) lift, international orange with white stripes on edges, and is mechanically released. It is attached to vehicle by 400m (1,312 ft) of electrical cable which serves as a hardwire telephone.
Jettisonable Components: Security weight - 400kg (883 lbs), four propellers - 120kg (265 lbs), manipulator - 130kg (287 lbs) and battery containers - 2,600kg (5,739 lbs).
Emergency Breathing: Three (Fenzy Mfg.), providing four hours for each occupant.
Communications Procedure: Check with surface every 15 minutes, abort dive if no contact with 30 minutes.

System Readiness: Under construction to be delivered in spring, 1976.
Classification/Certification: ABS and Veritas
Support Ship: M/V PROTEE (MOANA II), MOANA IV and V had no designated support ship at time of survey.
Owner: COMEX
13275 Marseille Cedex 2
France
Operator: Same as above
Builder: Same as above
Point-of-Contact: Gerard Chocteau of J.P. Marquinez
c/o COMEX
(Address same as above)
Telephone: 40.11.75 Marseille
Telex: 410985 COMEX MARSL

NEKTON ALPHA, BETA, GAMMA

CHARACTERISTICS

Length.....15 ft (4.6m)
Beam.....3.5 ft (1.1m)
Height.....6 ft (1.8m)
Draft.....4 ft (1.2m)
Weight (dry).....2.25 tons (2.3t)
Operating Depth..1,000 ft (305m)
Collapse Depth...2,500 ft (762m)
Launch Date.....1968, 70, 71

Hatch Diameter.....18 in. (45.7cm)
Life Support Duration.....144 man hrs
Total Power.....4.5 kWh
Speed: Cruise (kts/hrs)..1.5/3.5
Max (kts/hrs).....2/1
Crew: Pilot(s).....1
Observer(s).....1
Payload.....297 lbs (134kg)
Color.....Yellow

Pressure Hull: Cylindrical shape, composed of A-212 (ALPHA) and A-515 (BETA, GAMMA) mild steel, 9/16 in. (1.4cm) thick, 8 ft (2.4m) long and 3.5 ft (1.1m) ID. Conning tower is 2 ft (0.6m) diam. and 2 ft (0.6m) high.
Power Source: Eight 6 V, 190 amp-hr, lead acid batteries carried in the hull in a pressure-resistant compartment and delivering 24 V and 48 V. Auxiliary power is provided by a 12 V, 42 amp-hr lead acid battery in the hull, can run CO_2 scrubber system.
Maneuvering Control: Fixed, stern-mounted, reversible propeller. Starboard dive plane, rudder.
Life Support: Oxygen carried internally, two-72 ft^3 ($2.0m^3$) flasks at 2,200 psi ($154kg/cm^2$). CO_2 removed by soda sorb, 16 lbs (7.2kg) carried. O_2 continuously monitored, cabin pressure monitored by aircraft altimeter. Environmental check every 20 minutes. Scrubber power is off the main or auxiliary batteries.
Viewing: Seventeen viewports located in conning tower and bow. TV camera inside hull.
Manipulator: One, manually-powered, 38 in. (96.5cm) long rod with scissors grip. Not jettisonable.
Lift Point(s): Normal lifting is by two 3/8 in. (0.8cm) shackles forward and aft of conning tower connected by a bridle. Auxiliary lift is by a strongback trending athwart the conning tower. Strongback attachment points are circular, 3/4 in. (1.9cm) diam. penetrations drilled in 0.5 in. (1.3cm) thick steel plate. Any one of the four attachment points can sustain vehicle's entire dry weight.
External Lighting: Eight, 150 w, thallium iodide lights, three each p/s on bow, one each p/s on stern.
Surface Lights: None routinely carried. Occasionally carries a 150 w light on the scanning sonar dome which may be used intermittantly on the surface.
Emergency Food & Water: Water and food (candy) carried to provide endurance equal to that of life support. Exposure suits carried in cold water operations.
Surface Communications: VHF transceiver, 25 w, can operate off main and auxiliary power.
Sub-Surface Communications: One underwater telephone, 8.0875 kHz, powered off the main batteries. Communications check with surface every 35 minutes; if no communications within 70 minutes, the dive is aborted.
Sonars: Scanning sonar, manually trainable 360 degrees, audible display, mounted on conning tower (modified Straza Sea Probe) and operates in both active and passive mode. Active mode transmits and receives on 96 to 119 kHz, 200 yds (182m) max range, 19 degrees horizontal beam width. Passive mode receives 20 to 54 kHz. Self-powered, five days duration, can operate off main batteries. Pinger occasionally carried, 37 kHz, two sec. rep. rate, self-powered, 48 hr duration.

Jettisonable Components: Manually droppable 180 lb (81.5kg) weight; 25 lb (11.3kg) propulser/rudder assembly is droppable. MBTs and VBT can be blown at operating depth to provide 1,500 lbs (680kg) and 30 lbs (13.6kg) positive buoyancy, respectively.
Emergency Breathing: Scuba regulators (two each) draw off main ballasting air.
Egress Procedure (underwater): Hull can be flooded and occupants may egress carrying emergency breathing regulators with tanks. This is a last resort and 200 ft (60.8m) depth is considered maximum.

System Readiness: Operational
Classification/Certification: BETA and GAMMA: ABS; ALPHA: none
Support Ship: R/V DAWN STAR & R/V SEAMARK can be used, but normally a ship of opportunity is employed.
Owner: General Oceanographics, Inc.
11578 Sorento Valley Rd., Suite 25
San Diego, Calif. 92121
Operator: Same as above
Builder: Same as above
Point-of-Contact: Mr. Merle D. Wilson
General Oceanographics, Inc.
(Address same as above)
Telephone: (714) 452-1792

NEMO

CHARACTERISTICS

Length.....6.5 ft (2.0m)
Beam.....6.5 ft (2.0m)
Height.....9.2 ft (2.8m)
Draft.....7.2 ft (2.2m)
Weight (dry).....4.2 tons (3.8t)
Operating Depth..1,000 ft (305m)
Collapse Depth...4,200 ft (1,280m)
Launch Date.....1973

Hatch Diameter.....22 in. (56cm)
Life Support Duration.....270 man hrs
Total Power.....54 kWh
Speed: Cruise (kts/hrs)..NA
Max (kts/hrs).....1.25/NA
Crew: Pilot(s).....1
Observer(s).....1
Payload.....850 lbs (385kg)
Color.....Plastic hull with orange circumferential metal supports and black and white checkered battery pod

Pressure Hull: Spherical shape, composed of acrylic plastic, 66 in. (168cm) OD and 2.5 in. (6.4cm) thick. Hatch cover and a bottom plate for penetrators are cadmium-plated steel.
Power Source: Main power is from 21-6 V 150 amp-hr, pressure-compensated, lead acid batteries supplying 24 and 120 V. Auxiliary power is supplied by a silver zinc battery inside the pressure hull which provides 25.5 V for 20 hrs at 2 amp-hr to the CO_2 scrubber, underwater telephone, surface transceiver and battery/water intrusion switch.
Maneuvering Control: Two 1.5 hp hydraulic motors mounted p/s drive reversible, 14 in. (35.6cm) screw-type propellers to provide forward and lateral propulsion. An anchor and hydraulically powered winch provide static excursions in the vertical.
Life Support: Two 71 ft^3 ($2m^3$) capacity O_2 flasks are carried inside the pressure hull. CO_2 is removed by scrubbing cabin air through baralyme. Continuous monitors for O_2, CO_2, temperature and pressure. O_2 and CO_2 are checked every 15 minutes and a backup (Drager tube) reading is made every 60 minutes. Silica gel is carried in the pressure hull to control humidity. The auxiliary power can be used to operate CO_2 scrubber if the main power supply fails.
Viewing: Panoramic viewing through plastic pressure hull.
Lift Point: One, circular metal ring on a three point nylon rope bridle. Ring lays flat on hull during dive.
External Lighting: Four lights total. Two EG&G (500/700 w each) incandescent (one trainable) on centerline and two (Birns & Sawyer), 500 w each, p/s.
Surface Lights: Xenon flashing (Southwest Res. Inst. Mfg.), 24 in. (61cm) above water surface.
Anchor: Hydraulically powered winch/cable arrangement with a 500 lb (227kg) anchor clump.
Fire Extinguisher: One, dry chemical
Emergency Food and Water: Will be commensurate with life support duration.
Surface Communications: One HF transceiver (Johnson Mfg.)
Sub-Surface Communications: One underwater telephone (Hydro Products Mod. U811, 8.1 kHz, 4,000 yd (3,658m) range.
Sonars: One pinger (further details not available)
Marker Buoy: A 12 x 7 x 6 in. (30 x 18 x 15cm) rectangular piece of syntactic foam is attached to 800 ft (244m) of 1/8 in. (0.3m) nylon line and held in place by a metal rod. By activating a hand hydraulic pump, the retaining pin retracts to free the buoy. The buoy is international orange and has NEMO printed on two sides.

AD-A033 179 BUSBY (R FRANK) ASSOCIATES ARLINGTON VA F/G 13/10.1
REVIEW OF MANNED SUBMERSIBLE DESIGN, OPERATIONS, SAFETY AND INS--ETC(U)
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Jettisonable Components: Anchor - 400 lbs (181kg) and battery pack - 2,170 lbs (661kg). The MBT can be blown dry at operational depth to provide approximately 300 lbs (136kg) of positive buoyancy.
Emergency Breathing: Two closed-circuit devices (Westinghouse Min-o-lungs) provide approximately two hours for each occupant. Goggles are provided for smoke protection.

System Readiness: Operational
Classification/Certification: ABS (applied Sept. 1975). Was U.S.N. certified to 600 ft (183m) in 1973.
Support Ship: Ship of opportunity
Owner: U.S. Navy
Operator: Southwest Research Institute
8500 Culebra Rd.
San Antonio, Tx. 78228
Builder: U.S. Navy Civil Engineering Laboratory
Port Hueneme, Ca.
Point-of-Contact: Mr. Edward Briggs
Southwest Research Institute
(Address same as above)
Telephone: (512) 684-5111

PC5C

CHARACTERISTICS

Length.....22 ft (6.7m)	Hatch Diameter.....22 in. (55.9cm)
Beam.....4.7 ft (1.4m)	Life Support Duration.....NA
Height.....7.5 ft (2.3m)	Total Power.....16 kWh
Draft.....5.5 ft (1.7m)	Speed: Cruise (kts/hrs)..NA
Weight (dry).....NA	Max (kts/hrs).....NA
Operating Depth.....1,000 ft (305m)	Crew: Pilot(s).....2
Collapse Depth.....NA	Observer(s).....1
Launch Date.....1968	Payload.....700 lbs (319kg)
	Color.....Yellow

Pressure Hull: Cylindrical shape with hemispherical end caps, composed of SA 212B steel.
Power Source: Lead acid batteries (24 each) in pressure-resistant containers supply 12 VDC at 63 amp-hrs rate.
Maneuvering Control: Main forward propulsion is supplied by a fixed, reversible, stern-mounted propeller powered by a 7.5 hp motor. Two thrusters of fractional hp are mounted forward and aft. Dive planes and rudder assist in underway maneuvering.
Viewing: Twenty six viewports total, four in stern, nine girdle the conning tower and 13 are in the forward end cap.
External Lighting: One, 500 w, quartz iodide, mounted on the bow.
Life Jackets: Three, inflatable.
Surface Lights: One, white strobe light, 2 ft (0.6m) above water level, self-powered.
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Amount not yet specified, type will be the same as PS-2.
Sub-Surface Communications: One underwater telephone (Heele Mfg.), 27 kHz, one transducer mounted topside.
Jettisonable Components: One 881 lb (400kg) mechanically released weight.
Emergency Breathing: Three open-circuit regulators drawing off water deballasting air are provided. Approximately two hours is available to each occupant.

System Readiness: Overhaul
Classification/Certification: None
Support Ship: M/V CAPALONGA
Owner: Sub Sea Oil Services
Via S. Vittore
45 Milano
Italy
Operator: Same as owner
Builder: Perry Submarine Builders, Inc.
Riviera Beach, Florida
Point-of-Contact: Ing. G. Santi, Gen. Mgr.
Address same as owner
Telephone: 02-4983141
Cable: SUBSEA MILAN
Telex: 39204

PC8B

CHARACTERISTICS

Length.....18.5 ft (5.6m)
Beam.....5.75 ft (1.7m)
Height.....6.75 ft (2.1m)
Draft.....5 ft (1.5m)
Weight (dry).....5.5 tons (5t)
Operating Depth..800 ft (244m)
Collapse Depth...1,800 ft (549m)
Launch Date.....1971

Hatch Diameter.....22 in. (56cm)
Life Support Duration.....10 man days
Total Power.....20 kWh
Speed: Cruise (kts/hrs)..2.5/6
Max (kts/hrs).....4/2
Crew: Pilot(s).....1
Observer(s).....1
Payload.....250 lbs (113kg)
Color.....Yellow

Pressure Hull: Cylinder with hemispherical bow and conical end caps composed of low temperature carbon steel 13.7 ft (4.1m) long and 3/8 in. (0.95cm) thick.
Power Source: Lead acid batteries are carried within two pressure-resistant pods beneath the hull, providing 24 and 120 VDC.
Maneuvering Control: Static: One variable ballast of 160 lbs (73kg) capacity in the pressure hull which is free-flooding and pumped dry. Dynamic: All propulsion is provided by a stern-mounted, reversible propeller which is driven by a 7.5 hp motor within the pressure hull. Electro-hydraulic rudder and dive plane.
Life Support: Four O_2 flasks are located external to the hull and hold 72 ft^3 ($2.0m^3$) at 2,250 psi ($157kg/cm^2$). CO_2 is routinely removed by soda sorb, LiOH is carried for emergency use. Emergency batteries are carried in the hull for the CO_2 scrubber. O_2, CO_2, temperature and pressure are monitored on a schedule dependent upon pilot's work load.
Viewing: Plastic bow dome (114 degree spherical segment); eight viewports girdle conning tower and one is in the hatch cover. A TV camera with recorder is carried in the hull.
Manipulators: Two, both are electro-hydraulically powered and neither is jettisonable. One is capable of four degrees-of-freedom, it is 46 in. (117cm) long, has a scissors-type claw and can lift 75 lbs (34kg). The second is capable of five degrees-of-freedom, (360 degree wrist rotate), it is 48 in. (122cm) long, has a parallel jaws-type claw and can lift 75 lbs.
Lift Point: An inverted fishhook-shaped lift point with the open end facing forward and mounted at the center of gravity just after the conning tower. The hook is 2 5/8 in. (6.6cm) x 3 3/4 in. (9.5cm) wide and high, respectively, its maximum opening is 3 3/8 in. (8.1cm) and a counterweighted bar restrains the lift hauser from slipping out of the hook once it is engaged. The counterweighted bar also serves to prohibit the hook from fouling on lines or cables.
External Lighting: Six lights total, five look forward and one aft. All are quartz iodide, four are 250 w and two are 500 w.
Life Jackets: Two, inflatable
Smoke Pots: One, externally-mounted, electrically-activated flare fixed to the vehicle, color: black.
Surface Lights: One, flashing, white light 3.5 ft (1.1m) above the waterline, once every three seconds rep. rate, powered off the main batteries.
Fire Extinguisher: One, dry chemical
Emergency Food and Water: Food and water carried in amounts equal to ten man days life support. Food consists mainly of candies. Two gals (7.6 l.) of water are carried. Other food sources are being investigated.

Surface Communications: CB transceiver, 5nm (8km) range, operates off the main batteries.
Sub-Surface Communications: One (Helle Mod. 3600) underwater telephone, 27 kHz, CW mode, operates off main battery and emergency battery in pressure hull.
Sonars: Wesmar (Mod. SS150) scanning sonar, 150 kHz, 360 degree scan in the horizontal displays both PPI and audio, powered off main batteries. Vertical sector scan four degrees above horizontal and 90 degrees below horizontal. Pingers: One, operates off main batteries, 27 kHz (Electronic Applique Mfg.).
Directional Antennae: One (Helle Mfg.) receiving between 20-45 kHz, trained by moving the vehicle.
Jettisonable Components: Mechanically releaseable 450 lbs (204kg) weight. Both MBTs and VBTs can be blown at operating depth.
Emergency Breathing: Scuba regulators draw off main ballasting air. Facemasks provided.
Communications Procedure: Check with surface every 15 minutes. Abort dive after 30 minutes if no contact.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: M/V NADIR
Owner: Intersub
Estaque Gare - Chateau Bois
13016 Marseille
France
Operator: Same as above
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: J.F. Durand
Intersub
(Address same as above)
Telephone: (91) 46.02.36
46.10.73
Telex: 40 598 INTRSUB

PC-9 (TS-1)

CHARACTERISTICS

Length.....26 ft (7.9m)
Beam.....7.1 ft (2.2m)
Height.....8 ft (2.4m)
Draft.....5.3 ft (1.6m)
Weight (dry).....11.3 tons (10.2t)
Operating Depth..1,350 ft (411m)
Collapse Depth...2,500 ft (762m)
Launch Date.....1970

Hatch Diameter.....24 in. (60cm)
Life Support Duration.....250 man hrs
Total Power.....49.9 kWh
Speed: Cruise (kts/hrs)..1/16
Max (kts/hrs).....3/3
Crew: Pilot(s).....1
Observers.....2
Payload.....1,000 lbs (452kg)
Color.....Red above waterline, blue below

Pressure Hull: Cylindrical shape, SA-537 Grade A normalized steel 9/16 in. (1.4cm) thick, 4.5 ft (1.4m) ID, 18.2 ft (5.5m) length.
Power Source: Twin battery pods contain six V lead-acid heavy duty batteries providing 120 VDC main power (41.6 kWh at 20 hrs) and 24 VDC auxiliary power (8.3 kWh at 20 hrs)
Maneuvering Control: Static: Two internal, fore/aft tanks control fine buoyancy or trim by ±400 lbs (181kg). Dynamic: Main propulsion is from a variable speed, reversible, ten hp DC electric motor mounted in a water-tight container driving a stern propeller. One single speed reversible vertical bow thruster (1.5 hp) and two (1.5 hp) lateral thrusters provide low speed maneuvering. Hydraulically-activated bow planes and rudder control attitude underway.
Pitch/Trim: Two internal (fwd/aft) tanks of 91 lbs (41kg) capacity each can be differentially filled with sea water to attain up/down bow angles of ± ten degrees.
Life Support: Four oxygen flasks, 240 ft^3 (6.8m^3) capacity each at 2,250 psi (157kg/cm^2) are located externally. Soda sorb is used for routine removal of CO_2 and LiOH is carried in event of emergency. Every 15 minutes the following is monitored: O_2, CO_2, temperature, humidity and pressure. Backup devices are carried to monitor O_2 and CO_2.
Viewing: Twenty-one viewports, nine in the forward pressure hull, nine in conning tower and three aft. All are 6.25 in. (15.9cm) ID, 1.5 in. (3.8cm) thick, 8 in. (20.3cm) OD. Three television cameras total; all with video recorders. Two are mounted p/s, each is on a pan and tilt mechanism.
Manipulators: One, 5 ft (1.5m) length, hydraulically-powered, four degrees-of-freedom capable of lifting 50 lbs (23kg). Parallel jaws-type claw, non-jettisonable. A second manipulator is under construction and is 6 ft (1.8m) long, electro-hydraulically powered, six degrees-of-freedom and capable of lifting 250 lbs (113kg). Parallel jaws and scissors-type claws, jettisonable.
Lift Point: Main lift point is aft of the conning tower and is configured similar to an inverted fish hook with the hook or barb side aft. The hook is 4 in. (10.1cm) wide, 3 in. (7.6cm) thick and has a minimal opening of 3 in. (7.6cm). A safety bar is slid across the opening to hold the lift hauser securely in place.
External Lighting: Five units total, all mounted forward. Three are 400 w each quartz iodide and two are 200 w each thallium iodide.
Life Jackets: Three, inflatable
Surface Lights: Flashing (1/3 sec), white xenon light, 5 ft (1.5m) above waterline, self-powered, 50 hrs duration.
Fire Extinguisher: Two, dry chemical

Emergency Food & Water: Equal in duration to total life support (21 man days) with three man crew . Five pints (1.3 l.) of water are carried. Food consists of life boat type rations. Presently considering inclusion of protective clothing.
Surface Communications: One, VHF (155 mHz), three channel transceiver, 20 w power, can operate off main batteries or an emergency source in the hull. About 20 nm (37km) range.
Sub-surface Communications: One underwater telephone is carried and operates off the main batteries. It transmits and receives on either eight or 27 kHz.
Sonars: A Wesmar (Mod SS300) scanning sonar is mounted on the bow and can scan a 180 degree forward sector on 39 kHz. Display is PPI and audio. Pinger: The underwater telephone can act as a pinger with a one second rep. rate, 27 kHz, may be self-powered or may operate off the main batteries for a duration of three months.
Transponder (Beacon): An AMF Mod. 365 acoustic beacon may be activated at selectable pulses (ten-100 second intervals) by a self-contained clock which can be synchronized with a shipboard clock to obtain slant range and (with suitable shipboard receivers) relative bearing. The PC-9 beacon transmits on ten kHz, is self-powered and will operate for six months at a 30 second reply rate.
Directional Antennae: A pinger/receiver (Hydro Products) is mounted on the bow to receive a 27 kHz pulse. It is trained by rotating the submersible and has an audio display.
Marker Buoy: Emergency buoy consists of a 10 in. (25cm) diam., international orange Grimsby float which is manually released (through hydraulics) and tethered to 2,000 ft (609m) of 0.25 in. (0.6cm) diam. nylon line.
Jettisonable Components: Eight hundred pounds (362kg) of lead can be manually jettisoned. The MBTs and VBTs can be emptied at operational depth to provide 1,150 lbs (520kg) and 400 lbs (181kg) of positive buoyancy, respectively. One manipulator weighing 200 lbs (91kg) can be jettisoned.
Emergency Breathing: Three scuba regulators can draw off the main air ballasting supply. Duration unknown. Three facemasks are carried. Closed-circuit systems are being investigated.
Communications Procedure: Underwater telephone check with surface every 15 minutes. If 30 minutes transpires with no contact, the dive is aborted.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: M/V SUBSEA I and M/V BAY SHORE
Owner: P&O Subsea UK
P.O. Box 9T
Dents Wharf
Depot Rd.
Middlesbrough, Cleveland
England
Operator: Same as owner
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: Robert Eastaugh, Gen. Mgr.
Address same as operator
Telephone: Middlesbrough 41441
Telex: 587124

PC-1201

CHARACTERISTICS

Length.....22 ft (6.7m)
Beam.....5.75 ft (1.75m
Height.....8 ft (2.4m)
Draft.....6 ft (1.8m)
Weight (dry).....8 tons (7.2t)
Operating Depth..1,000 ft (305m)
Collapse Depth...2,000 ft (609m)
Launch Date.....1975

Hatch Diameter.....22 in. (56cm)
Life Support Duration.....10 man days
Total Power.....33 kWh
Speed: Cruise (kts/hrs)..2.5/8
Max (kts/hrs).....4/2
Crew: Pilot(s).....1
Observer(s).....1
Payload.....750 lbs (340kg)
Color.....Yellow

Pressure Hull: Cylindrical shape with hemispherical bow end cap and conical stern section. Hull diam. 42 in. (107cm).
Power Source: Lead acid batteries (48) in two pressure-resistant pods providing 24 and 120 VDC.
Maneuvering Control: Static: Main ballast tanks of 1,000 lbs (453kg) capacity and VBT of 160 lbs (72kg) capacity. Dynamic: Stern propeller, fixed and reversible (110 hp); two, one hp, reversible, fixed thrusters on bow, one for lateral and one for vertical movement. Rudder and dive planes electro-hydraulically controlled.
Life Support: Four O_2 flasks are located external to the hull and hold 72 ft^3 ($2.0m^3$) of gas at 2,250 psi ($157kg/cm^2$). CO_2 is routinely removed by soda sorb and LiOH is carried for emergency use. O_2 is bled continuously into the hull, and emergency batteries are carried in the hull for the CO_2 scrubber. O_2, CO_2, temperature and pressure are monitored on a schedule dependent upon work load.
Viewing: Plastic bow dome (114 degree spherical segment); eight viewports girdle conning tower and one in hatch cover. A TV camera with recorder is carried in the hull.
Manipulators: Two, both are electro-hydraulically powered and neither is jettisonable. One is capable of four degrees-of-freedom, it is 46 in. (117cm) long, has a scissors-type claw and can lift 75 lbs (34kg). The second is capable of five degrees-of-freedom, (360 degree wrist rotate), it is 48 in. (122cm) long, has a parallel jaws-type claw and can lift 75 lbs.
Lift Points: An inverted fish hook-shaped with the open end trending forward and mounted at the center of gravity just aft of the conning tower. The "hook" is 2 5/8 in. (6.6cm) x 3 3/4 in. (9.5cm) wide and high, respectively, its maximum opening is 3 3/8 in. (8.1cm) and a counterweighted bar restrains the lift hauser from slipping out of the hook once it is engaged. The counterweighted bar also serves to prohibit the hook from fouling on lines or cables.
External Lighting: Six lights total, five look forward and one aft. All are quartz iodide, four are 250 w and two are 500 w.
Life Jackets: Two, inflatable.
Smoke Pots: One, externally-mounted, electrically-activated flare fixed to the vehicle, color: black.
Surface Lights: One, flashing, white light 3.5 ft (1.1m) above the waterline, once every three seconds rep. rate, powered off the main batteries.
Fire Extinguisher: One, dry chemical.
Emergency Food & Water: Food and water carried in amounts equal to ten man days life support. Food consists mainly of candies, two gal (7.6 l.) of water are carried. Other food sources are being investigated.
Surface Communications: CB transceiver, 5nm (8km) range, operates off the main batteries.

Sub-Surface Communications: One (Helle Mod. 3600) underwater telephone, 27 kHz, CW, operates off main battery. An emergency power supply is carried in the pressure hull.
Sonars: Wesmar (Mod. SS150) scanning sonar, 160 kHz, 360 degree scan in the horizontal displays both PPI and audio, powered off main batteries. Vertical sector scan four degrees above horizontal and 90 degrees below horizontal. Pingers: One pinger operates off main batteries, 27 kHz. (Mfg. Electronic Applique).
Directional Antennae: One (Helle Mfg.) directional antennae receiving between 20-45 kHz, operates off main batteries, audible display, trained by moving submersible.
Jettisonable Components: Mechanically releaseable 450 lb (204kg) weight. Both MBTs and VBTs can be blown at operating depth.
Emergency Breathing: Scuba regulators draw off main ballasting air. Facemasks provided.
Communications Procedure: Check with surface craft every 15 minutes. Abort dive after 30 minutes if no contact has been made.

Systems Readiness: Operational
Classification/Certification: ABS
Support Ship: M/V SEA STORK
Owner: Intersub
Estaque Gare - Chateau Bois
13016 Marseille
France
Operator: Same as above
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: J.F. Durand
Intersub
Estaque Gare - Chateau Bois
13016 Marseille
France
Telephone: (91) 46.02.36
46.10.73
Telex: 40 598 INTRSUB

PC-1202

CHARACTERISTICS

Length.....31 ft (9.4m)	Hatch Diameter.....22 in. (56cm)
Beam.....8 ft (2.4m)	Life Support Duration.....15 man days
Height.....9 ft (2.7m)	Total Power.....53 kWh
Draft.....7 ft (2.1m)	Speed: Cruise (kts/hrs)..1.5/10
Weight (dry).....15 tons (6.8t)	Max (kts/hrs).....2.5/NA
Operating Depth..1,000 ft (305m)	Crew: Pilot(s).....1
Collapse Depth...2,000 ft (610m)	Observer(s).....4 (3 divers)
Launch Date.....1975	Payload.....1,500 lbs (680kg)
	Color.....Yellow

Pressure Hull: Cylindrical shape, steel, with hemispherical bow and conical stern. Inside diam. of pilot's (atmospheric pressure) compartment 48 in. (122cm); ID of LOC is 54 in. (137cm).
Power Source: Lead acid batteries. 24 & 120 VDC, 90 amp-hrs, carried in two droppable, pressure-resistant pods.
Maneuvering Control: Static: VBTs totaling 465 lbs (210kg) capacity. Dynamic: A ten hp, fixed, reversible stern propeller provides main propulsion; one vertical and two horizontal thrusters of one hp each provide auxiliary propulsion. Dive planes and rudder assist dynamic maneuvering.
Pitch/Trim: Up/down bow angles can be obtained by differentially filling the VBTs. Degrees of pitch unknown at time of survey.
Life Support: Four O_2 flasks of 72 ft^3 (2.0m^3) capacity each at 2,250 psi (157kg/cm^2) are carried externally. A total of 7,500 ft^3 (212m^3) of mixed gas (H_eO_2) is available for lockout diving. CO_2 is routinely removed by soda sorb and LiOH is carried for emergency use. O_2 is bled continuously into the hull and emergency batteries are carried in the hull for the CO_2 scrubber. O_2, CO_2, temperature and pressure are monitored on a schedule dependent upon occupant work load.
Viewing: Plastic bow dome (114 degree spherical segment); seven viewports girdle conning tower, one is in the hatch cover and two are in the LOC. A TV camera with recorder is carried in the hull.
Manipulators: Two, both are electro-hydraulically powered and neither is jettisonable. One is capable of four degrees-of-freedom, it is 46 in. (117cm) long, has a scissors-type claw and can lift 75 lbs (34kg). The second is capable of five degrees-of-freedom, (360 degree wrist rotate), it is 48 in. (122cm) long, has a parallel jaws-type claw and can lift 75 lbs.
Lift Points: One standard hook-shaped metal point aft of the conning tower with the opening pointing forward. The hook is 2 7/8 in. (7.1cm) wide, 3 3/8 in. (8.6cm) high and has a minimal opening of 4 in. (10.1cm). A counter-weighted metal bar holds in the lift line and also prevents the hook from fouling.
External Lighting: Eight lights total, all quartz iodide, six are mounted forward and two on the stern. The six forward lights are 250 w, the two stern lights are 500 w.
Life Jackets: Five, inflatable
Smoke Pots: One, externally-mounted, electrically activated flare fixed to the vehicle, color: black.
Surface Lights: One, flashing, white light 3.5 ft (1.1m) above the waterline, once every three seconds rep. rate, powered off the main batteries.
Fire Extinguisher: Two, in forward compartment, dry chemical.

Emergency Food & Water: Food and water carried in amounts equal to ten man days life support. Food consists mainly of candies. Five gals (18.9 l.) of water are carried. Other food sources are being investigated.
Medical Supplies: A medical lock chamber allows for passage of material from the atmospheric chamber to the LOC.
Surface Communications: CB transceiver, 5nm (8km) range, operates off the main batteries.
Sub-Surface Communications: One (Helle Mfg. Mod. 3600) underwater telephone, 27 kHz, CW mode, operates off the main battery and has an emergency power supply in the pressure hull.
Sonars: Wesmar (Mod. SS150) Scanning Sonar, 160 kHz, 360 degree scan in the horizontal, displays both PPI and audio, powered off main batteries. Vertical sector scan four degrees above horizontal and 90 degrees below horizontal. Pingers: One, operates off main batteries, 27 kHz. (Mfg. Electronic Applique).
Jettisonable Components: Both battery pods are hydraulically droppable and total 3,000 lbs (1,359kg).
Emergency Breathing: Scuba regulators draw off main ballasting air. Facemasks provided.
Egress Procedure: Exit from the LOC is an established routine. No provisions are made to exit from the forward compartment.
Communications Procedure: Check with surface every 15 minutes. Abort dive after 30 minutes if no contact has been made.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: M/V SEA DIVER
Owner: Intersub
Estaque Gare - Chateau Bois
13016 Marseille
France
Operator: Same as above
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: J.F. Durand
Intersub
(Address same as above)
Telephone: (91) 46.02.36
46.10.73
Telex: 40 598 INTRSUB

PC-1203

CHARACTERISTICS

Length.....22 ft (6.7m)
Beam.....7.8 ft (2.4m)
Height.....7.9 ft (2.4m)
Draft.....5.6 ft (1.7m)
Weight (dry).....8 tons (7.3t)
Operating Depth..1,000 ft (305m)
Collapse Depth...2,000 ft (610m)
Launch Date.....1976

Hatch Diameter.....22.75 in. (57.8cm)
Life Support Duration.....160 man hrs
Total Power.....35.1 kWh
Speed: Cruise (kts/hrs)..1/12
Max (kts/hrs).....3/NA
Crew: Pilot(s).....1
Observer(s).....1
Payload.....725 lbs (33kg)
Color.....Gray, white, orange

Pressure Hull: Cylindrical shape with hemispherical end cap on bow and conical shaped stern section, 48 in. (121cm) ID.
Power Source: Lead acid batteries in pressure-resistant pods providing 29.3 kWh at 120 VDC and 5.8 kWh at 24 VDC.
Maneuvering Control: Static: MBTs of 800 lbs (362kg) capacity; VBT of ±180 lb (397kg) capacity. Dynamic: Main propulsion from a stern-mounted, fixed, reversible ten hp, screw-type propeller, two thrusters on bow one vertical and one lateral. Rudder and dive planes.
Life Support: Oxygen carried inside hull in four flasks totaling 423 ft^3 ($12m^3$) at STP. CO_2 is removed by LiOH. Monitors for O_2, CO_2, temperature and humidity.
Viewing: Eight viewports all 8 in. (20cm) major diam., seven girdle the conning tower and one is in the hatch cover. One 36 in. (91cm) diam. plastic, hemispherical bow dome. One TV in hull.
Manipulators: Two, one with five and one with six degrees-of-freedom (wrist rotate in one). Both hydraulically-powered, 68 in. (173cm) total length, parallel jaws-type claws with max opening of 4 in. (10cm) and 600 lbs (272kg) maximum grip force. Lift at maximum extension is 120 lbs (54kg). Not jettisonable.
Lift Points: NA
External Lighting: Four total. Two, 500 w each on bow, quartz iodide; one each p/s, 300 w each.
Life Jackets: Two, inflatable
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Equal to life support duration.
Surface Communications: CB and VHF, (23 channel, 27 mHz) transceivers.
Sub-Surface Communications: One (Mesotech Mfg.) dual frequency (8 & 27 kHz) underwater telephone outputting at 20 & 100 w.
Sonars: Scanning sonar: One, (SS 140 S Wesmar), 160 kHz. Echo sounder: One, (Kode Mfg.) multiscale looking either up, forward or down, 8 kHz.
Jettisonable Components: Keel weight of 400 lbs (181kg). MBT blow and VBT pump at operating depth provides a total of 980 lbs (444kg) positive buoyancy.
Emergency Breathing: Two Fenzy, closed-circuit breathing devices of four hrs duration each.

System Readiness: Under construction as of January 1976.
Classification/Certification: ABS
Support Ship: M/V PROTEE

Owner: COMEX
13275 Marseille Cedex 2
France
Operator: Same as owner
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: G. Chocteau and/or J.L. Somnier
COMEX
(Address same as owner)
Telephone: (91) 40.11.70
Telex: 41.985 COMEX-MARSI

PC-14C-2

CHARACTERISTICS

Length.....19.6 ft (6m)
Beam.....5.9 ft (1.8m)
Height.....8 ft (2.4m)
Draft.....6 ft (1.8m)
Weight (dry).....5.9 tons (5.4t)
Operating Depth..600 ft (183m)
Collapse Depth...1,800 ft (549m)
Launch Date.....1975

Hatch Diameter.....21 1/4 in. (56cm)
Life Support Duration.....180 man hrs
Total Power.....17 kWh
Speed: Cruise (kts/hrs)..1/5
Max (kts/hrs).....2.5/1
Crew: Pilot(s).....1
Observer(s).....1
Payload.....400 lbs (181kg)
Color.....Yellow

Pressure Hull: Cylindrical shape with conical (stern) and hemispherical (bow) end caps, composed of A 537 Cl.1 steel 3/8 in. (0.15cm) thick and a bow section of acrylic plastic 36 in. (91cm) diam. Cylinder is 42 in. (107cm) diam. and 6.9 ft (2.1m) length.
Power Source: Lead acid batteries in a jettisonable, pressure-resistant pod consisting of 15, 12 V batteries in five, 36 V banks delivering 475 amp-hrs. One auxiliary battery of 12 V at 95 amp-hrs.
Maneuvering Control: One stern-mounted, reversible propeller powered by a three hp motor. Can turn 360 degrees in a 30 ft (9.1m) diam. circle. Static maneuvering by filling or pumping dry a 100 lb (45kg) capacity VBT.
Pitch/Trim: No systems available, however, a roll angle of $\pm$5 to 10 degrees can be obtained by differentially filling the MBTs.
Life Support: Five flasks of O_2 at 2,000 psi (140kg/cm^2) totaling 120 ft^3 (3.4m^3) are carried inside the pressure hull. Six qts (5.7 l.) of baralyme are routinely carried to scrub CO_2; two cannisters of LiOH are carried for emergency use. Monitors for O_2, CO_2, pressure and temperature. Backup monitors for O_2 and CO_2. O_2 is bled continuously into hull and monitored every 30 min.
Viewing: Bow view dome of 36 in. (91cm) diam. and eight, 8 in. (20cm) diam. viewports in conning tower.
Lift Point: One shackle mounted 2 ft (0.7m) aft of conning tower and trending athwartships. Shackle is 5 in. (13cm) major inside length and 3.75 in. (9.5cm) inside width. Shackle lays flat during dive.
Life Jackets: One, inflatable
Fire Extinguisher: One, dry chemical
Surface Communications: VHF-FM transceiver, 173.8 mHz, operates off 12 VDC from main batteries.
Sub-Surface Communications: One underwater telephone (Heele Mod. 3600), 27 kHz, operates off main batteries.
Sonar: Pinger: One, self-powered, rep. rate: one/sec., duration three to four days, salt water and/or manually activated, 45 kHz.
Marker Buoys: A marker buoy is towed to track vehicle during every dive.
Jettisonable Components: Battery pod of 2,500 lbs (1,133kg) is manually releaseable. MBTs and VBT can be emptied at maximum operating depth to provide 580 lbs (263kg) of positive buoyancy.
Emergency Breathing: Scuba regulators and mouth pieces draw off MBT air blow, 540 man min. are estimated as the systems duration.
Communications Procedure: Dive aborted after 20 minutes if no contact with surface.
Egress Procedure (underwater): May be accomplished by flooding hull through VBT manifold and compartment vent.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: M/V NEPTUNE
Owner: U.S. Army
Ballistic Missile Defense Systems Command
P.O. Box 1500
Huntsville, Alabama 35807
Operator: Kentron Hawaii Ltd.
(KMR Technical Support Contractor)
Builder: Perry Submarine Builders, Inc.
Riviera Beach, Fla. 33404
Point-of-Contact: Neal McLemore
P.O. Box 1207
APO San Francisco 96555
or
Kentron Hawaii Ltd.
2003 Byrd Spring Rd.
Huntsville, Alabama 35802
Telephone: (205) 883-9690

PC-16

CHARACTERISTICS

Length.....25 ft (7.6m)	Hatch Diameter.....
Beam.....8 ft (2.4m)	Life Support Duration.....240 man hrs
Height.....9 ft 6 in. (3m)	Total Power.....52 kWh
Draft.....NA	Speed: Cruise (kts/hrs)..1/8
Weight (dry).....15 tons (13.6t)	Max (kts/hrs).....2/1½
Operating Depth..3,000 ft (914m)	Crew: Pilot(s).....1
Collapse Depth...4,500 ft (1,372m)	Observer(s).....2
Launch Date.....1976	Payload.....750 lbs (340kg)
	Color.....NA

Pressure Hull: Three interconnected (bolted) steel spheres, 72 in. (183cm) diameter. Two hatches, one atop forward sphere and one under middle sphere for dry, one atmosphere, transfer.

Power Source: Lead acid batteries in pressure-resistant, droppable pods. Batteries supply 120 V and 24 VDC.

Maneuvering Control: Main propulsion is provided by a ten hp electric motor driving a screw-type, reversible, stern-mounted propeller. Three thrusters for low speed maneuverability, two are mounted on bow planes and can be oriented in the vertical or horizontal plane, the third is also on the bow and provides lateral thrust. Rudder and bow planes are electro-hydraulically driven.

Pitch/Trim: A variable buoyancy/trim system consisting of two external hard tanks of 200 lbs (91kg) capacity can be used to obtain ± bow angles.

Life Support: O_2 is carried externally and can be bled continuously into the pressure hull. Two CO_2 scrubbers (one each in the forward and middle sphere) utilizing LiOH. Three, man-powered breathing systems are included which consist of face mask, hose and cannister. Primary and backup monitors for O_2 and CO_2, monitors for temperature, humidity and cabin pressure.

Viewing: Eight viewports total. Six girdle the conning tower and one is in the hatch cover. The eighth is in the dry transfer hatch cover. The forward sphere includes a 30 in. (76cm) diameter, acrylic plastic dome.

Manipulators: Two hydraulically-powered, mounted forward on the bow. Maximum length 55 in. (140cm), lift capacity - 75 lbs (34kg) at maximum extension. Two types of claws, one is parallel jaws; the second is scissors-type, maximum opening - 3 in. (7.6cm), 200 lbs (91kg) grip force. The manipulator with the parallel jaws claw has wrist rotate. The scissors-type claw manipulator has two degrees-of-freedom, linear extension, but no wrist rotate. Manipulators are not jettisonable.

Lift Point: Single point lift consisting of a steel padeye located amidships aft of the conning tower. Three circular aperatures in the padeye allow for variations in trim.

External Lighting: Two, 500 w each (Birns & Sawyer Mod. 5565), incandescent lights mounted forward on bow guard rail.

Life Jackets: Three, inflatable

Surface Lights: Flashing white strobe, 0.1 w second flash once every two seconds, approximately 100 hrs duration. Visibility estimated at 22nm (40.8km) from aircraft.

Fire Extinguisher: Dry chemical (quantity undecided at time of survey).

Surface Communications: CB transceiver (Lafayette HB-525), 5 w output, 23 channels, 27 mHz. A sound-powered telephone will be provided for intercompartmental communications.

Sub-Surface Communications: One, underwater telephone (Mesotech Mfg.) transmitting on 8 or 27 kHz.
Sonars: Scanning sonar (Wesmar SS1405) transmitting on 160 kHz, range - 1,600 ft (488m). Transducer is laterally trainable 360 degrees and can be tilted in the vertical plane to four degrees upward or 90 degrees downward from the horizontal. In the 90 degree downward mode it may act as an echo sounder.
Jettisonable Components: Battery pods
Emergency Breathing: Four face masks and regulators are connected to the high pressure air system which consists of two tanks holding 2,000 ft^3 (57m3) at 5,000 psi (352kg/cm^2).

System Readiness: Operational (May 1976)
Classification/Certification: ABS
Support Ship: NA
Owner: Intersub
Estaque Gare - Chateau Bois
13016 Marseille
France
Operator: Same as owner.
Builder: Perry Submarine Builders
Riviera Beach, Florida
Point-of-Contact: J.F. Durand
Intersub
(Address same as owner)
Telephone: (91) 46.02.36
46.10.73
Telex: 40598 INTRSUB

PISCES II

CHARACTERISTICS

Length.....5.8m (19 ft)
Beam.....3.2m (10.5 ft)
Height.....3.1m (10.2 ft)
Draft.....2.3m (7.5 ft)
Weight (dry).....12.4 tons (11.3t)
Operating Depth.....2,400 ft (731m)
Collapse Depth.....5,000 ft (1,524m)
Launch Date.....1969

Hatch Diameter.....19.5 in. (49.5cm)
Life Support Duration.....352 man hrs
Total Power.....40 kWh
Speed: Cruise (kts/hrs)..NA
Max (kts/hrs).....2/4
Crew: Pilot(s).....1
Observer(s).....2
Payload.....1,500 lbs (679kg)
Color.....Red

Pressure Hull: Spherical shape, Corten B Steel 6.7 ft (2.03m) OD.
Power Source: Lead acid batteries, pressure-compensated, divided into main and auxiliary sections. Main batteries: 60 x 2 V,320 amp-hr; Auxiliary: 60 x 12 V,90 amp-hr.
Maneuvering Control: Two propulsion units consisting of two, reversible, screw-type propellers mounted p/s, each unit is driven by a three hp motor.
Pitch/Trim: Oil is pumped forward or aft to provide approximately ± 15 degrees bow angle.
Life Support: Four flasks of O_2 are carried, two are located in the pressure hull and hold 64 ft^3 ($1.8m^3$) each and two are carried externally and hold 70 ft^3 ($2m^3$) each. CO_2 is removed by scrubbing through LiOH. Monitors for CO_2, CO, temperature, humidity and pressure; monitoring of these properties is every 15 minutes.
Viewing: Three viewports, all on the bow looking forward. Television camera mounted externally on training mechanism.
Manipulators: Two, both hydraulically-powered and both have jettisonable claws. One has two degrees-of-freedom and is designed for 2,000 lbs (906kg) grasping capacity. The second has six degrees-of-freedom and is designed for 200 lbs (90.6kg) grasping capacity. The heavy lift manipulator has an opposing "C"-shaped claw, the lighter lift manipulator has a parallel jaws-type claw.
Lift Points: A flat, steel plate shaped into a "Rams Horns" configuration. Two holes in the plate; one is circular and approximately 2.5 in. (6.3cm) ID; the second is elliptical and approximately 4 in. (10.1cm) long and 2.5 in. (6.3cm) wide.
External Lighting: Three, 1,000 w each, quartz iodide lights mounted forward above viewports.
Life Jackets: Two, inflatable
Fire Extinguisher: Two, dry chemical
Emergency Food and Water: Seven pints (3.3 l.) of canned water for each occupant and dehydrated food equal to 14 man days of lift support. Two pair wool socks, two sweaters, two thermal blankets.
Medical Supplies: First aid kit
Surface Communications: VHF transceiver operating on 157.65, 156.80 and 156.65 mHz. Range approximately 3nm (5.6 km).
Sub-Surface Communications: One underwater telephone (Subcom Mod. 2005-20B) transmitting on 10 or 27 kHz. Four transducers - two face upward and two down, emergency power provided.
Sonars: Scanning sonar (Wesmar SS1205) trainable ± 90 degrees p/s and transmitting on 155 kHz. Pinger mode in underwater telephone, emits on 10 or 27 kHz, one ping every three seconds, emergency 24 V power supply provided. Transponder (AMF Mfg.) receives on 10 kHz, responds on 11 kHz.

Marker Buoy: One, red, rounded (Grimsby Mfg.), metal float, 8 in. (20cm) diameter.
Jettisonable Components: Propulsion motors (two each), 400 lbs (181kg) weight, manipulator claws. Total weight approximately 828 lbs (375kg).
Emergency Breathing: Three, self-contained, oxygen rebreathers providing 15 minutes for each occupant.
Communications Procedure: Surface check every 15 minutes, dive is aborted if communications are not established after 30 minutes.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: VICKERS series
Owner: Vickers Oceanics, Ltd.
P.O. Box 8
Barrow-in-Furness
Cumbria
England, LA13 1AD
Operator: Vickers Oceanics, Ltd.
Old Dock
Leith
Edinburgh EH6 6ND
Scotland
Builder: International Hydrodynamics, Ltd.
No. Vancouver, B.C.
Canada
Point-of-Contact: Base Duty Officer
Vickers Oceanics, Ltd.
(Address same as operator)
Telephone: 031 554 0676 (Leith)
Telex: 72248

PISCES III

CHARACTERISTICS

Length.....20.6 ft (6.3m)
Beam.....10.8 ft (3.3m)
Height.....10.5 ft (3.2m)
Draft.....7.5 ft (2.2m)
Weight (dry).....12.9 tons (11.7t)
Operating Depth.....3,000 ft (915m)
Collapse Depth.....8,894 ft (2,711m)
Launch Date.....1969

Hatch Diameter.....20.9 in. (53cm)
Life Support Duration.....352 man hrs
Total Power..... 40 kWh
Speed: Cruise (kts/hrs)..NA
Max (kts/hrs).....2/NA
Crew: Pilot(s).....1
Observer(s).....2
Payload.....1,500 lbs (680kg)
Color.....White

Pressure Hull: Spherical shape, Corten B steel, 6.7 ft (2.03m) OD.
Power Source: Lead acid batteries, pressure-compensated, divided into main and auxiliary sections. Main batteries: 60 x 2 V,320 amp-hr; Auxiliary: 60 x 12 V,90 amp-hr. Emergency power in pressure hull provides 12 V at 20 amp-hr (Sonnenchein ST).
Maneuvering Control: Two propulsion units consisting of two, reversible, screw-type propellers mounted p/s, each unit is driven by a three hp motor.
Pitch/Trim: Oil is pumped forward or aft to provide approximately $\pm$ 15 degrees bow angle.
Life Support: Five flasks of O_2 are carried, three are located in the pressure hull and hold 64 ft^3 ($1.8m^3$) each, two are located externally and hold 70 ft^3 ($2m^3$) each. CO_2 is removed by scrubbing through LiOH. Monitors for O_2, CO_2, temperature, humidity and pressure; monitoring of these properties is approximately every 15 minutes.
Viewing: Three viewports on bow, all look forward. Television mounted externally on training mechanism.
Manipulators: Two, both hydraulically-powered and both have jettisonable claws. One has two degrees-of-freedom and is designed for 2,000 lbs (906kg) grasping capacity. The second has six degrees-of-freedom and is designed for 200 lbs (90.6kg) grasping capacity. The heavy lift manipulator has an opposing "C"-shaped claw; the lighter lift manipulator has a parallel jaws-type claw.
Lift Points: A flat, steel plate shaped into a "Rams Horns" configuration. Two holes in the plate; one is circular and approximately 2.5 in. (6.3cm) ID; the second is elliptical and approximately 4 in. (10.1cm) long and 2.5 in. (6.3cm) wide.
External Lighting: Three, 1000 w each, quartz iodide lights mounted forward above viewports.
Life Jackets: Two, inflatable
Surface Lights: Flashing white light, 3 ft (0.9m) above water surface, once every three seconds flash rate, self-powered.
Fire Extinguisher: Two, dry chemical
Emergency Food & Water: Seven pints (3.3 l.) of canned water for each occupant and dehydrated food equal to 14 man days of life support. Two pair wool socks, two sweaters, two thermal blankets.
Medical Supplies: First aid kit
Surface Communications: VHF transceiver operating on 157.65, 156.80 and 156.65 mHz. Range approximately three nm (5.6 km). Emergency power supply provided.
Sub-Surface Communications: One underwater telephone (Subcon Mod. 2005-20B) transmitting on 10 or 27 kHz. Four transducers, two face upward and two down, emergency power provided.

Sonars: Scanning sonar (Wesmar SS120S) trainable ± 90 degrees p/s and transmitting on 155 kHz. Pinger mode in underwater telephone, emits on 10 or 27 kHz, one ping every three seconds. Transponder (AMF Mfg.) receives on 10 kHz, responds on 11 kHz. Directional Hydrophone (Helle Mfg.), receiving on 10 and 27 kHz.
Marker Buoys: One, red, 10 in. (25.4cm) diameter sphere attached to 4,000 ft (1,219m) of line.
Jettisonable Components: Propulsion motors (two each), 450 lbs (204kg) weight, manipulator claws. Total weight approximately 883 lbs (400kg).
Emergency Breathing: Three (Emox Mfg.) self-contained, oxygen rebreathers provide 45 minutes for each occupant.
Communications Procedure: Surface check every 15 minutes, dive aborted if communications not established after 30 minutes.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: VICKERS series
Owner: Vickers Oceanics, Ltd.
P.O. Box 8
Barrow-in-Furness
Cumbria
England LA14 1AD
Operator: Vickers Oceanics, Ltd.
Old Dock
Leith
Edinburgh EH6 6ND
Scotland
Builder: International Hydrodynamics, Ltd.
No. Vancouver, B.C.
Canada
Point-of-Contact: Base Duty Officer
Vickers Oceanics, Ltd.
(Address same as operator)
Telephone: 031 554 0676 (Leith)
Telex: 72248

PISCES IV

CHARACTERISTICS

Length.....20 ft (6.1m)	Hatch Diameter.....19.4 in. (49.3cm)
Beam.....10 ft (3.0m)	Life Support Duration.....180 man hrs
Height.....12 ft (3.6m)	Total Power.....46.2 kWh
Draft.....8 3/4 ft (2.7m)	Speed: Cruise (kts/hrs)..0.5/10
Weight (dry).....27,790 lbs (10,360kg)	Max (kts/hrs).....2/0.5
Operating Depth..6,600 ft (2,000m)	Crew: Pilot(s).....1
Collapse Depth...9,000 ft (2,743m)	Observer(s).....2
Launch Date.....1972	Payload.....1,000 lbs (452kg)
	Color.....White; orange day-glow sail

Pressure Hull: Spherical shape, HY-100 steel, 80 in. (2.03m) diam., 1.038 in. (2.63cm) thick.
Power Source: Lead acid batteries, 120 V, 385 amp-hr, pressure compensated.
Maneuvering Control: Two, five hp each, reversible thrusters mounted p/s amidships. Thrusters are rotatable 90 degrees upward to 30 degrees downward from the horizontal.
Life Support: Four O_2 flasks of 73.3 ft^3 (2.1m^3) capacity each are carried in pressure hull. O_2 is continuously supplied at 0.4 l./min/man. CO_2 is routinely removed by Dragersorb and five, 6.4 lb (2.9kg) capacity (each) LiOH cannisters are carried for emergency. O_2 is monitored every 20 minutes. CO_2 can be monitored if required. Cabin pressure is displayed and monitored in concert with O_2.
Viewing: Three viewports all forward on bow. TV mounted on external pan and tilt with internal recorder. Hand-held TV carried in pressure hull.
Manipulators: Two carried; a PHA and a heavy lift. The PHA has six degrees-of-freedom, 115 lb (52kg) lift capacity, scissors-type claw, claw jettisonable. Heavy duty manipulator: three degrees-of-freedom, 1,500 lbs (679kg) grasping capacity, opposable "C" shaped-type claw, jettisonable.
Lift Point(s): There are five points to which the submersible can be lifted; one is primary and four are secondary. Primary: A standard 15 ton (13.6t) lift hook mounted on a swivel immediately aft of sail. Hook folds into sail to avoid entanglement while diving. Secondary: One at each corner of main frame (used to secure vehicle in aircraft) each consisting of a 7/8 in. (2.2cm) diam. bar steel with a hemispherical opening divided into a 2 in. (5.0cm) by 2 5/8 in. (6.6cm) rectangular opening.
Lighting (underwater): Two, 1,000 w, tungsten iodide lights on bow.
Life Jackets: Three, inflatable
Distress Rockets: Under consideration
Radar Reflector: Under consideration
Surface Lights: One xenon, white flashing light, 36 in. (91cm) above water surface, self-powered with a flash rate of once every five seconds.
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Sufficient for nine man days. Three "space" blankets for thermal protection, first aid kit also carried.
Surface Communications: One CB transceiver operating off main battery.
Sub-Surface Communications: One underwater telephone operating on 8.875 kHz with an upward and downward-looking transducer. Operates off both the main battery and an emergency power supply. Is capable of CW and pinging mode (27 kHz).

Surface Homing Devices: A hand-held, aircraft-type radio beacon is carried in pressure hull. It is self-powered, 48 hrs duration and transmits on 121.5 and 243.0 mHz.
Sonars: Transponder: self-powered, transmits or can be interrogated on 23, 24, 26, 27 kHz. Scanning sonar: Wesmar S140 Sea Scope, range: 1,600 ft (487m) tiltable, four degrees upward and 90 degrees downward from the horizontal, operates on 16.5 kHz.
Emergency Buoyancy: Manually droppable weight: 385 lbs (174kg); thrusters droppable; 56 lbs (25kg) each; PHA claw droppable: 19 lbs (8.6kg); Heavy Duty manipulator claw droppable: 65 lbs (29kg).
Emergency Breathing: Nine Drager closed-circuit emergency breathing devices are carried, each provides 30 minutes life support.
Communications Procedure: Check with surface every 15 minutes, dive aborted after 30 minutes if no contact.
Egress Procedure (underwater): Pressure hull can be flooded and high pressure air introduced to equalize internal pressure to ambient. Hatch is opened and life jackets donned to assist ascent. Procedure is a "last ditch" resort and limited to 200 ft (91kg) depth.

System Readiness: Operational
Classification/Certification: ABS classed to 2,400 ft (797m)
Support Ship: M/V PANDORA II
Owner: Department of the Environment
Pacific Region
512-1230 Government St.
Victoria, B.C. V8W1Y4
Canada
Operator: Same as above
Builder: International Hydrodynamics, Ltd.
Vancouver, B.C.
Point-of-Contact: Mr. G. Meek
Address same as owner
Telephone: (604) 656-5611
Cable: 0448137

PISCES V

CHARACTERISTICS

Length.....20 ft (6.1m)	Hatch Diameter.....19.4 in. (49.3cm)
Beam.....10 ft (3.0m)	Life Support Duration.....168 man hrs
Height.....12 ft (3.6m)	Total Power.....39 kWh
Draft.....8.75 ft (2.7m)	Speed: Cruise (kts/hrs).....0.5/10
Weight.....10.9 tons (9.8t)	Max (kts/hrs).....2/4
Operating Depth....6,600 ft (2,000m)	Crew: Pilot(s).....1
Collapse Depth.....9,000 ft (2,743m)	Observer(s).....2
Launch Date.....1973	Payload.....1,000 lbs (455kg)
	Color.....White

Pressure Hull: Spherical shape, composed of HY-100 steel 80 in. (2.03m) diameter, 1.038 in. (2.54cm) thick.
Power Source: Lead acid batteries, 120 V 330 amp-hr, pressure compensated.
Maneuvering Control: Two, five hp each, reversible thrusters are mounted p/s amidships. Thrusters are rotatable 90 degrees upward to 30 degrees downward from the horizontal.
Life Support: Five flasks of O_2 are carried, three are located within the pressure hull and hold 64 ft^3 ($1.8m^3$) each, two are located externally and hold 70 ft^3 ($2m^3$) each. CO_2 is removed by scrubbing cabin air through LiOH. Monitors for O_2, CO_2, temperature, humidity and pressure, monitoring of these properties is approximately every 15 minutes.
Viewing: Three viewports on bow, all look forward. Television mounted externally on training mechanism.
Manipulator: Two, both hydraulically-powered and both have jettisonable claw. One has two degrees-of-freedom and is designed for 2,000 lb (906kg) grasping capacity used for torpedo recovery. The second has six degrees-of-freedom and is designed for 200 lb (90.6kg) grasping capacity. The heavy lift manipulator has an opposing "C"-shaped claw; the lighter lift manipulator has a parallel jaws-type claw.
Lift Point(s): A standard 15 ton (13.6t) hook mounted on a swivel immediately aft of the sail.
Life Jackets: Three, inflatable
Surface Lights: Flashing white xenon light, 3 ft (0.9m) above water surface, flash rate 1/3 seconds, self powered. Duration: 36 hours.
Fire Extinguisher(s): Two
Emergency Food and Water: Equal to duration of life support. Five pints (1.3 l.) of water is carried for each occupant. Food consists of life boat type C rations. Protective (thermal) clothing and blankets.
Surface Communications: VHF transceiver operates on 157.65, 156.80 and 156.65 mHz. Range approximately 3 nm (5.6 km). Emergency power supply provided.
Sub-Surface Communications: One underwater telephone is carried and operates off the main batteries. It transmits and receives on either 10 or 27 kHz.
Sonars: A Wesmar (Mod. SS140) scanning sonar is mounted on the bow and can scan a 180 degree forward sector. Display is PPI and audio. Pinger: The underwater telephone can act as a pinger with a one second rep rate on 27 kHz and may be self-powered or operate off the main batteries for a duration of three months. An AMF (Mod. 365) acoustic beacon is carried which may be activated at selectable pulses (10 to 100 second intervals) by a self-contained clock. The beacon clock can be synchronized with a shipboard clock to obtain slant range and (with suitable shipboard receivers) relative bearing. The beacon transmits on 10 kHz, is self-powered and will operate for six months at a 30 second repetition rate.

Directional Antennae: A pinger/receiver (Hydro Products) is mounted on the bow to receive a 27 kHz pulse. It is trained by rotating the submersible and has an audio display.
Marker Buoys: Emergency buoy consists of a 10 in. (25cm) diam., international orange Grimsby float which is manually released (through hydraulics) and tethered to 2,000 ft (609m) of 0.25 in. (0.6cm) diam. nylon line.
Jettisonable Components: Propulsion motors (two ea.), 450 lbs (204kg) weight, manipulator claws 120 lbs (54kg). Total weight approximately 800 lbs (364kg). Droppable weight 400 lbs (181kg).
Emergency Breathing: Three (Draeger) self-contained, oxygen rebreathers provide 45 minutes for each occupant.
Communications Procedure: Surface check every 15 minutes, dive aborted if communications not established within 30 minutes.

System Readiness: Operational. (On lease to Vickers Oceanics, Ltd.)
Classification/Certification: ABS
Support Ship: Ship of Opportunity
Owner: Hyco Subsea Ltd.
P.O. Box 1059
Station "A"
Vancouver, B.C.
Canada
Operator: Vickers Oceanics Ltd.
Builder: International Hydrodynamics Ltd.
North Vancouver, B.C.
Point-of-Contact: Mr. A. McClean
Address same as owner
Telephone: (604) 681-0346
(604) 688-8607
Telex: 04-55465

PISCES VII & XI

CHARACTERISTICS

Length.....19.25 ft (5.85m)	Hatch Diameter.....19.4 in. (49.3cm)
Beam.....10 ft (3.05m)	Life Support Duration.....216 man hrs
Height.....12 ft (3.65m)	Total Power.....46.2 kWh
Draft.....8.75 ft (2.7m)	Speed: Cruise (kts/hrs)..0.5/10
Weight (dry).....11.75 tons (10.7t)	Max (kts/hrs).....2/4
Operating Depth..6,600 ft (2,012m)	Crew: Pilot(s).....2
Collapse Depth...10,000 ft (3,048m)	Observer(s).....1
Launch Date.....1975	Payload.....1,500 lbs (679kg)
	Color.....Red: Sail
	White: Fairing
	Green: Pressure Hull

Pressure Hull: Spherical shape, 80 in. (2.03m) OD, HY-100 steel, 1.038 in. (2.52cm) thick.
Power Source: Lead acid batteries, pressure compensated, provides 350 amp-hr at 120 VDC and 125 amp-hr at 12 and 24 VDC.
Maneuvering Control: Two thrusters mounted p/s amidships, each is five hp, reversible and has continuously variable speed control. Both are jettisonable and can be rotated 25 degrees upward from the horizontal and 95 degrees downward from the horizontal.
Pitch/Trim: Sea water can be pumped forward or aft to provide for $\pm$ 10 to $\pm$30 degrees bow angle.
Life Support: Five flasks of O_2 10.5 qts (ten l.) capacity each bled continuously into hull. CO_2 is removed by scrubbing through CaOH for a period of 10 -15 minutes every 30 minutes. Every 30 minutes the following properties are monitored: O_2, CO_2, temperature, humidity and pressure. Both O_2 and CO_2 monitors have backup monitoring devices.
Viewing: Three viewports on the bow. External TV and recorder.
Manipulators: Two manipulators, a PHA and a heavy lift. The PHA has six degrees-of-freedom,115 lbs (52kg) lift capacity and a scissors-type claw, 7 in. (0.18cm) grip which is jettisonable from the wrist. The heavy lift manipulator has three degrees-of-freedom, 1,500 lbs (675kg) grasping capacity and a jettisonable, 28 in. (0.71m) "C" shaped claw when opened.
Lift Point: A 1 in. (2.54cm) thick standard shackle constitutes the main lift point. This may change when the vehicles become operational.
External Lighting: Two quartz iodide, 100 w each, mounted forward.
Life Jackets: Three, inflatable
Distress Rockets: Will have; undecided at time of survey.
Fire Extinguishers: One, dry chemical
Emergency Food & Water: Food and water carried equal to life support. Food will be space craft-type rations; five l. (5.3 qts) of water. Protective thermal clothing is being investigated.
Medical Supplies: First aid kit
Surface Communications: CB and VHF transceivers,operate off main batteries,two to three nm (3.7-6.5km) range.
Sub-Surface Communications: One underwater telephone (Mesotech Mfg.), ten and 27 kHz, powered off main batteries.

Surface Homing Devices: Radio transponder provides range and bearing to support ship, self-powered, 64 hrs duration.
Sonars: Scanning Sonar (Wesmar Mod. SS140S) 160 kHz, 1,600 ft (500m) range, 360 degree scan, CRT display, beam width seven degrees, transducer tilt adjustable from the horizontal plane four degrees upward to 90 degrees downward.
Marker Buoys: Syntactic foam segments are shaped into a rectangular block approximately 3 ft x 3 ft x 2 ft (91cm x 91cm x 61cm) which is stored topside over a circular drum. The block is hydraulically-released and upon ascent reels out 5/16 in. (0.8cm) diam. "Phillystran" line which has a breaking strength of six tons (5.4t) and is 2 km (1.1nm) long. The buoy is red and white striped and the Phillystran line can be directly used to retrieve the vehicle. The original Hyco design allows for attachment of a radio transmitter, flashing light atop the buoy and an acoustic pinger on the bottom (underwater) of the buoy for surface location.
Jettisonable Components: One 400 lb (181kg) lead weight, propulsion motors, claws of both manipulators. Total weight droppable: 596 lbs (270kg).
Emergency Breathing: Three, closed circuit (Drager Mfg.) breathing devices providing 30 minutes/occupant.
Communications Procedure: Surface check every 30 minutes, abort dive if no contact is made after 60 minutes.

System Readiness: PISCES VII undergoing sea trials in USSR. PISCES XI is under construction in Canada.
Classification/Certification: ABS
Support Ship: R/V AKADEMIK KURCHATOV and DMITRI MENDELEEV
Owner: Academy of Sciences USSR
Moscow
Operator: P.P. Shirshov Institute of Oceanology
Academy of Sciences USSR
1 Letnay St., Moscow 109387
USSR
Builder: International Hydrodynamics Ltd.
Vancouver, B.C.
Canada V6C 2P1
Point-of-Contact: Mr. A. Monin, Director
Institute of Oceanology USSR
Address same as operator
Telephone: 233-55-76
Cable: G-387 OCEANOLOGIYA

PISCES VIII & X

CHARACTERISTICS

Length	20.5 ft (6.2m)
Beam	10.8 ft (3.3m)
Height	10.6 ft (3.2m)
Draft	NA
Weight (dry)	11.75 tons (10.7t)
Operating Depth	3,280 ft (1,000m)
Collapse Depth	4,921 ft (1,500m)
Launch Date	PVIII - 1975 PX - 1975
Hatch Diameter	20.9 in. (53cm)
Life Support Duration	336 man hrs
Total Power	40 kWh
Speed: Cruise (kts/hrs)	NA
Max (kts/hrs)	2/NA
Crew: Pilot(s)	1
Observer(s)	1
Payload	2.25 tons (2.04t)
Color	White

Pressure Hull: Spherical shape, Corten B steel 6.7 ft (2.03m) OD.
Power Source: Lead acid batteries, pressure-compensated, divided into main and auxiliary sections. Main batteries: 60 x 12 V, 320 amp-hr; Auxiliary: 60 x 12 V, 90 amp-hr. Emergency power in pressure hull provides 12 V at 20 amp-hr.
Maneuvering Control: Two propulsion units consisting of two, reversible, screw-type propellers mounted p/s, each unit is driven by a three hp motor.
Pitch/Trim: Oil is transferred forward or aft to provide approximately ± 15 degrees bow angle.
Life Support: Five flasks of O_2 are carried, three are located in the pressure hull and hold 64 ft^3 ($1.8m^3$) each, two are located externally and hold 70 ft^3 ($2m^3$) each. CO_2 is removed by scrubbing through LiOH. Monitors for O_2, CO_2, temperature, humidity and pressure; monitoring of these properties is approximately every 15 minutes.
Viewing: Three viewports on bow, all look forward. Television mounted externally on training mechanism.
Manipulators: Two, hydraulically-powered, jettisonable claws. One has two degrees-of-freedom and is designed for 2,000 lbs (906kg) grasping capacity. The second has six degrees-of-freedom and is designed for 200 lbs (90.6kg) grasping. The heavy lift manipulator has an opposing "C"-shaped claw; the lighter lift manipulator has a parallel jaws-type claw.
Lift Points: A flat, steel plate shaped into a "Rams Horns" configuration. Two holes in the plate; one is circular and approximately 2.5 in. (6.3cm) ID; the second is elliptical and approximately 4 in. (10.1cm) long and 2.5 in. (6.3cm) wide.
External Lighting: Three, 1000 w each, quartz iodide lights mounted forward above viewports.
Life Jackets: Two, inflatable
Surface Lights: Flashing white light, 3 ft (0.9m) above water surface, one flash every three seconds, self-powered.
Fire Extinguisher: Two, dry chemical
Emergency Food & Water: Seven pints (3.3 l.) of canned water for each occupant and dehydrated food equal to 14 man days of life support.
Medical Supplies: First aid kit.
Surface Communications: VHF transceiver operated on 157.65, 156.80 and 156.65 mHz. Range approximately three nm (5.6 km). Emergency power supply provided.
Sub-Surface Communications: One underwater telephone (Subcon Mod. 2005-20B) transmitting on 10 or 27 kHz. Four transducers, two face upward and two down, emergency power provided.

Sonars: Scanning sonar (Wesmar SS1205) trainable ± 90 degrees p/s and transmitting on 155 kHz. Pinger mode in underwater telephone, emits on 10 or 27 kHz, one ping every three seconds. Transponder (AMF Mfg.) receives on 10 kHz, responds on 11 kHz. Directional Hydrophone (Helle Mfg.) receiving on 25 through 40 kHz.
Marker Buoys: One, red, 10 in. (25.4cm) diameter sphere attached to 4,000 ft (1,219m) of line.
Jettisonable Components: Propulsion motors (two each), 450 lbs (204kg); manipulator claws. Total weight approximately 883 lbs (400kg).
Emergency Breathing: Three, (Emox Mfg.), closed-circuit oxygen rebreathers provide 45 minutes for each occupant.
Communications Procedure: Surface check every 15 minutes, dive aborted if communications not established after 30 minutes.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: VICKERS series
Owner: Vickers Oceanics, Ltd.
P.O. Box 8
Barrow-in-Furness
Cumbria
England LA14 1AD
Operator: Vickers Oceanics, Ltd.
Old Dock
Leith
Edinburgh EH6 6ND
Scotland
Builder: International Hydrodynamics, Ltd.
No. Vancouver, B.C.
Canada
Point-of-Contact: Base Duty Officer
Vickers Oceanics, Ltd.
(Address same as operator)
Telephone: 031 554 0676 (Leith)
Telex: 72248

PRV-2

CHARACTERISTICS

Length.....21 ft (6.4m)
Beam.....7.9 ft (2.4m)
Height.....8 ft (2.4m)
Draft.....6 ft (1.8m)
Weight (dry).....8.2 tons (7.4t)
Operating Depth..1,000 ft (305m)
Collapse Depth...2,100 ft (640m)
Launch Date.....1976

Hatch Diameter.....22 in. (55.8cm)
Life Support Duration.....123.5 man hrs
Total Power.....46.5 kWh
Speed: Cruise (kts/hrs)..2/6
Max (kts/hrs).....3.4/1.4
Crew: Pilot(s).....1
Observer(s).....2
Payload.....1,040 lbs (471kg)
Color.....White

Pressure Hull: Cylindrical shape, SA516 GR-70 steel with dished end caps. Total length 9.5 ft (2.9m), 4 ft (1.2m) ID, 5/8 in. (1.6cm) thick.
Power Source: Lead acid batteries in pressure compensated pod providing 12, 24 or 36 VDC. Dry cell batteries in hull for emergency use of transceiver and underwater telephone.
Maneuvering Control: Three thrusters, four hp each, stern-mounted and trainable 29 degrees p/s in the horizontal plane provide main forward and lateral propulsion. Two vertical thrusters, 1.4 hp each, reversible mounted p/s amidships.
Pitch/Trim: Battery pod can be moved forward or aft to compensate for varying payloads forward.
Life Support: Five O_2 flasks carried externally. CO_2 is removed by scrubbing through soda sorb, LiOH carried for emergency use. Monitors for O_2, CO_2 and pressure.
Viewing: Forty one inch (104cm) diameter acrylic plastic bow dome.
Manipulator: One, 400 lbs (181kg) lift capacity, not jettisonable. Not constructed at time of survey.
Lift Point(s): An eight inch (20.3cm) diameter one inch (2.54cm) thick steel ring is attached to the vehicle by a three-point bridle made of nylon webbing.
External Lighting: Two, 350 w each, quartz iodide (Birns & Sawyer Mod. 5562) lights, one mounted on bow, one mounted to illuminate area below lockout hatch.
Life Jackets: Three, inflatable
Distress Flares: Will carry, not installed at time of survey.
Surface Lights: One, flashing white, xenon light (OAR Mod. SF-500-1-100), 0.1 watt-second, one flash/two seconds, self-powered, 100 hrs duration, 2 ft (0.6m) above water surface. Standard navigation (running) lights will be included.
Fire Extinguisher: Three, dry chemical
Medical Supplies: First aid kit. Lock for transfer of medical supplies to lock out chamber.
Surface Communications: CB. Details not available at time of survey
Sub-Surface Communications: One underwater telephone, 8 kHz. (Hydro Products Mfg.).
Jettisonable Components: Battery pod weighing 4,900 lbs (2,220kg) in air is dropped by activating release with hydraulic hand pump.
Emergency Breathing: Three scuba

System Readiness: Operational by April 1976
Classification/Certification: ABS
Support Ship: Ship of opportunity

Owner: Minisub Associates
Albertson, L.I., N.Y.
Telephone: (516) 484-1040
Operator: Same as above
Builder: Pierce Submersibles, Inc.
204 N. Fehr Way
Bayshore, N.Y. 11706
Telephone: (516) 242-5264 or 5291
Point-of-Contact: Robert H. Pierce
Pierce Submersibles, Inc.
(Address and telephone same as builder)

PS-2

CHARACTERISTICS

Length.....19.5 ft (5.9m)	Hatch Diameter.....22 in. (55.8cm)
Beam.....6 ft (1.8m)	Life Support Duration.....288 man hrs
Height.....7 ft (2.1m)	Total Power.....22 kWh
Draft.....5 ft (1.5m)	Speed: Cruise (kts/hrs)..1/8
Weight (dry).....6.5 tons (5.9t)	Max (kts/hrs).....3/1
Operating Depth.....1,200 ft (366m)	Crew: Pilot(s).....2
Collapse Depth.....2,000 ft (610m)	Observer(s).....1
Launch Date.....1972	Payload.....400 lbs (181kg)
	Color.....Yellow

Pressure Hull: Cylindrical with conical stern and hemispherical bow end caps. Composed of A-516-GR70 steel.
Power Source: Lead acid batteries carried in two pressure-resistant pods. Twenty four batteries total supplying 24 VDC at 92 amp-hrs rate.
Maneuvering Control: Main forward propulsion is provided by a fixed, reversible, stern-mounted propeller powered by a 7.5 hp motor. Two, reversible thrusters provide vertical propulsion. Dive plane and rudder assist in providing underway control.
Life Support: Four O_2 tanks are carried externally and hold 1.4 ft^3 (40 l.) each at 2,400 psig (169kg/cm^3). CO_2 is removed by scrubbing through LiOH. Monitors for O_2, CO_2, temperature, humidity and pressure. All properties are checked once every 15 minutes.
Viewing: One 114 degree acrylic plastic bow dome. Eight viewports are located in the conning tower and hatch cover. External television camera on a pan and tilt mechanism.
Manipulator: One, hydraulically-powered, three degrees-of-freedom, parallel jaws type claw, 6 ft (1.8m) long, not jettisonable.
Lift Points: A steel plate located topside immediately aft of the conning tower is perforated by three holes approximately 1 in. (2.54cm) ID, the plate is 2 in. (5cm) thick.
External Lighting: Two, 1,000 w each, quartz iodide lights are mounted p/s forward on the bow.
Life Jackets: Two, inflatable
Distress Rockets: Ten white and ten red, 20mm rockets are carried inside the pressure hull and fired through the opened hatch from a very pistol.
Surface Lights: One, white, self-powered, strobe light mounted 2 ft (60cm) above the water surface with a duration exceeding 12 hours.
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Twenty litres (42 pts) of potable water. Chocolate, dextrose and ship's biscuit. Equivalent to life support duration. Sweaters, caps and tights also carried.
Medical Supplies: First aid kit, anti-burn cream, methedryne pills.
Surface Communications: One, VHF transceiver
Sub-Surface Communications: One underwater telephone (Heele Mod. UT-01-PVC), 27 kHz, one transducer mounted topside.
Sonars: Scanning sonar (Wesmar Mod. SS160S), 160 kHz, 360 degree scan, PPI display. Pinger (Wesmar Mfg.) included as component of scanning sonar.
Marker Buoy: One carried, no details available.
Jettisonable Components: One 250 lb (114kg) weight is mechanically released.
Emergency Breathing: Two open-circuit regulators drawing off water deballasting air are provided. Approximately two hours is available to each occupant.

Communications Procedure: Check with surface once every 15 minutes, abort dive if no surface contact within 30 minutes.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: M/V CAPALONGA
Owner: Sub Sea Oil Services
Via S. Vittore
45 Milano
Italy
Operator: Same as owner
Builder: Perry Submarine Builders, Inc.
Riviera Beach, Florida
Point-of-Contact: Ing. G. Santi, Gen. Mgr.
Address same as owner
Telephone: 02-4983141
Cable: SUBSEA MILAN
Telex: 39204

SDL-1

CHARACTERISTICS

Length.....20 ft (6.1m)
Beam.....10 ft (3.0m)
Height.....12 ft (3.7m)
Draft.....9 ft (2.7m)
Weight (dry).....13 tons (11.8t)
Operating Depth..2,000 ft (610m)
Collapse Depth...4,000 ft (1,220m)
Launch Date.....1970

Control 25 in. (63.5cm)
Hatch Diameter.....LOC 22.75 in. (57.8cm)
Life Support Duration.....204 man hrs
Total Power.....64 kWh
Speed: Cruise (kts/hrs)..1/8
Max (kts/hrs).....1.5/5
Crew: Pilot(s).....1
Observer(s).....1
Diver(s).....3
Payload.....1,300 lbs (588kg)
Color.....White with international orange sail

Pressure Hull: Two HY-100 steel spheres connected by a cylindrical tunnel to form a forward control sphere and an after LOC. The control sphere is 7 ft (2.1m) OD and 0.50 in. (1.27cm) thick; the LOC is 5.5 ft (1.7m) OD and 0.50 in. (1.27cm) thick and the connecting cylinder is 26 in. (66cm) ID, 71 in. (180cm) long and 0.75 in. (1.9cm) thick.

Power Source: Lead acid batteries, pressure-compensated, supply 60, 120, 12 and 28 volts from three separate banks totaling 495 amp-hrs. Emergency power for the underwater telephone is supplied by two 15 V nickel cadmium batteries inside the pressure hull.

Maneuvering Control: Two, five hp, p/s mounted, reversible, variable speed thrusters provide forward and lateral propulsion. Thrusters are fixed in the horizontal plane, but may be operated independently to provide lateral maneuvering.

Pitch/Trim: Bow angles of $\pm$30 degrees can be obtained by moving one of the battery packs and droppable lead weights forward or aft.

Life Support: O_2 is carried externally in one 750 ft^3 (21m^3) tank at 3,000 psi (212kg/cm^2) and internally in two 60 ft^3 (1.7m^3) tanks. CO_2 is removed by scrubbing through Dragersorb, one scrubber in control sphere, one in LOC. Monitors for O_2, CO_2, temperature and pressure; these properties are checked every 20 minutes.

Viewing: Ten viewports total, all are located in the control sphere.

Manipulators: Two, both hydraulically-powered, both have jettisonable claws. One (called the PHA) is 5.5 ft (1.7m) long, has six degrees-of-freedom, a parallel jaws-type claw of 4 in. (10cm) maximum opening and a grip force of 1,000 lbs (452kg). The other (called the Torpedo claw) is 36 in. (91cm) long, has three degrees-of-freedom, two opposing C-type claws of 10 in. (25cm) and 8 in. (20cm) ID, and a grip force of 2,000 lbs (904kg).

Lift Points: The main lift point is a 1.5 in. (3.8cm) thick standard shackle with major and minor IDs of 5.5 in. (13.9cm) and 3.5 in. (8.9cm), respectively. The shackle is located within the sail immediately aft of the sail hatch opening, it is held in an upright position while submerged. One additional lift point is located on each corner of the supporting framework, (four points total) these are 0.5 in. (1.27cm) diameter circular holes drilled through 3/16 in. (0.5cm) thick steel plates. The four additional lift points cannot support the entire vehicle weight, but can be used to lift it to some depth near the surface.

External Lighting: Four lights total, all are 1,000 w, quartz iodide. Three illuminate the forward viewing area, one illuminates the area below the LOC.

Life Jackets: Four, inflatable

Surface Lights: One, flashing white, (OAR Mod. SF-500-1-100), self-powered, 100 hrs duration at rep. rate of one flash/second, 3 ft (0.9m) above water level.
Fire Extinguisher: Two, dry chemical
Emergency Food & Water: Survival candies carried which provide a food supply equal to life support duration. Forty eight 12 oz (0.35 l.) cans of water. Sleeping bags carried for each occupant. Super mylar "Space Suits" are carried for each occupant.
Medical Supplies: First aid kit
Surface Communications: VHF transceiver (Motorola HT220), 5 nm (9.3km) range, self-powered, four channels (156.700, 156.750, 156.800, 156.850).
Sub-Surface Communications: One underwater telephone (Ametek Straza Mod. ATM-504A), 8.0875 kHz, CW, operates off main or emergency power. Two transducers, one is mounted on the sail and one on the keel.
Sonars: Scanning sonar (Wesmar SS150), 160 kHz, PPI and audio, 360 degree scan, can scan from four degrees above the horizontal to 90 degrees below the horizontal. Pinger (Heele Mfg.), 27 kHz, self-powered, duration depends upon rep. rate which is selectable, must be activated prior to diving. Transponder (AMF Mod. 360 Acoustic Beacon), transmits on 8.0875 kHz, self-powered.
Marker Buoy: None, if dive will be greater than 200 ft (61m) a buoyed 1.5 in. (3.8cm) diameter nylon line is always attached which will lift 8,000 lbs (3,616kg).
Jettisonable Components: Two weights each weighing 250 lbs (113kg), manipulator claws, motors.
Emergency Breathing: Six scuba regulators draw off MBT air supply and provide a minimum of six hrs for each occupant. Face masks provided.
Egress Procedure: Routine egress from LOC. Investigating the possibility of locking out from 500 ft (152m).
Communications Procedure: Check with surface every 20 minutes, dive aborted if no contact is established within 25 minutes.

System Readiness: In overhaul at time of survey; planned operational by late spring of 1976.
Classification/Certification: ABS and to Canadian Armed Forces standards
Support Ship: HMCS GRANBY (ASXL-20)
Owner: Canadian Armed Forces
Operator: Fleet Diving Unit Atlantic
CFB Shearwater
Shearwater, Nova Scotia BOJ 3AO
Canada
Builder: International Hydrodynamics, Ltd.
No. Vancouver, B.C.
Canada
Point-of-Contact: Commanding Officer
Fleet Diving Unit Atlantic
(Address same as operator)
Telephone: (902) 463-5111 or ext. 377 or 276

SEA CLIFF & TURTLE

CHARACTERISTICS

Length.....26 ft (7.9m)	Hatch Diameter.....19.75 in. (50.2cm)
Beam.....12 ft (3.7m)	Life Support Duration.....111 man hrs
Height.....12 ft (3.7m)	Total Power.....30 kWh
Draft.....7.5 ft (2.3m)	Speed: Cruise (kts/hrs).....0.5/8
Weight (dry).....25 tons (23t)	Max (kts/hrs).....2.5/2
Operating Depth..6,500 ft (1,981m)	Crew: Pilot(s) & Co-pilot...2
Collapse Depth...9,750 ft (2,972m)	Observer(s).....1
Launch Date.....1968	Payload.....NA
	Color.....White with orange sail

Pressure Hull: Spherical shape, HY-100 steel, 7 ft (2.1m) OD, 1.5 in. (3.8cm) thick.
Power Source: Lead acid batteries, pressure compensated, 30 and 60 VDC, each rated at 500 amp-hrs. Emergency power consists of two silver zinc batteries (12 amp-hrs each) inside the hull which provide power for communications, CO_2 scrubber, jettisoning and internal lights
Maneuvering Control: One propeller which is stern-mounted, reversible and trainable 45 degrees p/s provides main propulsion. Two thrusters mounted p/s amidships are trainable 360 degrees in the vertical and reversible (about 600 lbs lift) four hp each.
Pitch/Trim: By transferring mercury forward or aft TURTLE can obtain bow angles of ±10 degrees; SEA CLIFF ±17.5 degrees.
Life Support: O_2 is carried inside the pressure hull in two flasks. One (for routine use) has a volume of 0.6 ft^3 (0.02m^3) and is charged to 3,000 psi (210kg/cm^2), the second (for emergency use) has a volume of 175 $in.^3$ (2,868cm^3) and is charged to 2,015 psi (142kg/cm^2). CO_2 is routinely removed by scrubbing through LiOH. Baralyme is used in the emergency system. O_2, CO_2, temperature, humidity and pressure are monitored continuously and recorded once every 60 minutes. Backup O_2 and CO_2 monitors (Beckman and Drager, respectively) are carried.
Viewing: Five viewports total, four large and one small. The large viewports are oriented to look forward, vertically downward and p/s of the forward looking port. The small viewport is located in the hatch cover.
Manipulator(s): Two, hydraulically-powered, six degrees-of-freedom with wrist rotate and linear extension, various claw types (scissors, parallel jaws, cable cutters), jettisonable.
Lift Point: One consisting of a 1.75 in. thick (4.4cm) wire strap coiled in the sail area which is attached to the pressure sphere lift points and protrudes some 4 in. (10cm) above sail. The strap can support the entire weight of the forebody.
External Lighting: Four thallium iodide lights one is on the bow one on the pan and tilt and two are on the sponsons, 250 watts each. One bow-mounted quartz iodide.
Life Jackets: Three, inflatable
Radar Reflector: One, inside sphere, expandable wire mesh, circular shape.
Surface Lights: One, flashing white, one flash every four seconds, self-powered. Approximately 4 ft (1.2m) above water surface, pressure-activated. Also carries a battery-powered fog horn.
Fire Extinguisher: One, dry chemical
Emergency Food & Water: Whatever is onboard for daily dive consumption

Surface Communications: Two, one radio transceiver, UHF, 5 channel, 20 watt, 20 miles (37km) range. The second is self-powered and hand-carried.
Sub-Surface Communications: One (Straza 504 with TIPE option), 8.0875 kHz, CW (8.887 kHz). Two transducers, both topside, one transmits in a conical beam and one is omnidirectional.
Sonars: CTFM scanning sonar (Ametek/Straza Mod. 500), 72 to 87 kHz, CRT, 360 degrees scan. Echo sounder with upward and downward-looking transducers. TURTLE operates on 50 kHz with 1,200 ft (366m) range; SEA CLIFF operates on 23 kHz with 3,000 ft (914m) range. An AMF ATNAV system will be installed on both.
Jettisonable Components: Manipulators, batteries, selected weights, and sphere.
Emergency Breathing: Three full face masks, closed-circuit, draws off emergency O_2 and scrubs through baralyme, 98 minutes per user.
Communications Procedure: Contact surface every 30 minutes, abort dive if no contact within 30 minutes.

System Readiness: Operational
Classification/Certification: Both are U.S. Navy certified
Support Ship: M/V MAXINE "D" and ships of opportunity
Owner: U.S. Navy
Operator: Submarine Development Group One
San Diego, Ca. 92132
Builder: Electric Boat Division
General Dynamics Corp.
Groton, Conn.
Point-of-Contact: Commander
Submarine Development Group One
San Diego, Ca. 92132
Telephone: (714) 225-6583

SEA EXPLORER

CHARACTERISTICS

Length.....15.25 ft (4.6m)
Beam.....4.5 ft (1.4m)
Height.....5 ft (1.5m)
Draft.....2.5 ft (0.7m)
Weight (dry).....2 tons (1.8t)
Operating Depth..600 ft (183m)
Collapse Depth...2,000 ft (609m)
Launch Date.....1970

Hatch Diameter.....24 in. (61cm)
Life Support Duration.....48 man hrs
Total Power.....12 kWh
Speed: Cruise (kts/hrs)..1.75/4
Max (kts/hrs).....7/1
Crew: Pilot(s).....1
Observer(s).....1
Payload.....300 lbs (136kg)
Color.....Yellow

Pressure Hull: Cylindrical shape with elliptical end caps composed of fiber-reinforced plastic 2 in. (5cm) thick.
Power Source: Lead acid batteries in pressure hull deliver 30 V at 420 amp-hr.
Maneuvering Control: One, stern-mounted, reversible and trainable (85 degrees p/s) main propeller and one bow thruster capable of 360 degree rotation in the vertical plane. Both propellers are hydraulically-powered off a ten hp electric pump.
Life Support: Eighty ft^3 ($2.24m^3$) of O_2 at 2,000 psi ($140kg/cm^2$) carried inside pressure hull which is added to atmosphere as needed. CO_2 scrubber uses soda-sorb. Monitor for cabin pressure only (barometer) which is used to infer amount of O_2 in hull.
Viewing: Nineteen viewports located throughout vehicle.
Lift Points: Two, one located on port side of after conning tower and one located on starboard side of forward conning tower. Both are circular in shape; composed of 0.75 in. (1.9cm) thick stainless steel and 1.75 in. (4.4cm) ID. Either attachment is capable of sustaining entire vehicle weight.
Lighting (underwater): Six lights total all are incandescent aircraft lights and operate off 30 VDC. Two are 250 w, three are 450 w and one is 150 w.
Life Jackets: Two, inflatable.
Surface Lights: Two aircraft lights on the conning tower can be turned on and off intermittantly to assist in location.
Sub-Surface Communications: A sound-powered telephone is used to communicate with the surface. Dive is aborted if communications are lost. Occasionally uses a wireless telephone (Heele Eng. Co.) which operates off main battery on 27 kHz.
Marker Buoys: Four. Extruded from a tube by compressed air. Not attached to vehicle. Each buoy is composed of a 6 lb (2.7kg) lead weight, a 40 lb (18kg) test nylon string and an orange-colored, cylindrical buoy 6 in. (15.2cm) long and 4 in. (10.2cm) diam.
Jettisonable Components: The keel can be manually dropped to provide 625 lbs (283kg) positive buoyancy. MBTs can be blown at max. operating depth to provide 800 lbs (362kg) positive buoyancy.
Emergency Breathing: Each life jacket is equipped with a 2 ft^3 ($.05m^3$) capacity flask of compressed air. The compressed air is used to inflate jacket, but can also be used as emergency breathing through a mouthpiece on each jacket. Approximately ten minutes of breathing time is obtained from each jacket.
Egress Procedure (underwater): Hull can be flooded to allow personnel to exit underwater.

System Readiness: Operational
Classification/Certification: None
Support Ship: Ship of opportunity
Owner: Sea-Line, Inc.
3325 227th St., S.W.
Brier, Wa. 98036
Operator: Same as above
Builder: Same as above
Point-of-Contact: R.J. Levigueure
Address same as above
Telephone: (206) 778-3917

SEA OTTER

CHARACTERISTICS

Length.....13.5 ft (4.1m)
Beam.....5 ft (1.5m)
Height.....7.2 ft (2.3m)
Draft.....5.5 ft (1.7m)
Weight (dry).....3.2 tons (2.9t)
Operating Depth..1,500 ft (457m)
Collapse Depth...3,650 ft (1,113m)
Launch Date.....1971

Hatch Diameter.....19 in. (48.3cm)
Life Support Duration.....200 man hrs
Total Power.....13.8 kWh
Speed: Cruise (kts/hrs)..1/6
Max (kts/hrs).....3/1.5
Crew: Pilot(s).....1
Observer(s).....2
Payload.....500 lbs (249kg)
Color.....Yellow

Pressure Hull: Two, 0.625 in. (1.6cm) thick, mild steel, hemispheric sections are welded to the ends of a 0.75 in. (1.9cm) thick, 57.0 in. (145cm) long, 48.0 in. (10cm) wide, mild steel cylinder, with a 0.75 in. (1.9cm) thick, 19.0 in. (48cm) diameter hatch tower welded to the pressure hull.
Power Source: Twelve 2-volt lead acid batteries provide 13.8 kHz. They are located inside the pressure hull and are equipped with catalyzers to eliminate hydrogen.
Maneuvering Control: A three hp DC motor drives a trainable, stern-mounted propeller for main propulsion. Two 0.5 hp DC horizontal thrusters, located fore and aft, provide steering. A hydraulically controlled rudder is mounted on the main thruster. A 0.5 hp vertical thruster is mounted forward.
Pitch/Trim: Bow angle of ±15 degrees is attained by putting air or water in either the main or forward ballast tanks.
Life Support: Three 40 ft^3 ($.8m^3$) tanks of oxygen carried inside hull is continuously bled into the hull. Scrubbing of CO_2 is accomplished by recirculating air through a 6.4 lb (2.9kg) lithium hydroxide cannister. CO_2 and atmospheric pressure are measured periodically.
Viewing: Four viewports forward on bow; two p/s viewports also forward. Three viewports are located in the hatch tower and one viewport is located in the hatch cover.
Manipulator(s): One, six degrees-of-freedom linear extension,not jettisonable, 50 lb (22kg) lift capacity, 62 in. (1.5m) total length. Dorrance type claw.
Lift Point(s): Two metal padeyes 5/8 in. (1.6cm) thick located forward and aft of conning tower with circular opening of 1 in. (2.5cm) diam. One padeye can lift entire vehicle.
Lighting (underwater): A total of six lights are carried on brow. They are quartz iodide, 250 w, air compensated (Ikelite Mfg.).
Life Jackets: Two, inflatable
Distress Flares: One day/night (red/white) hand-held flare carried in pressure hull. Whistle also carried by pilot
Fire Extinguisher: One, dry chemical
Emergency Food and Water: One gal. (3.8 l.) water, four day supply food (candy bars).
Medical Supplies: First aid kit.
Surface Communications: CB transceiver, 5 w, 23 channel (Johnson Messenger).
Sub-Surface Communications: Two underwater telephones. Primary system is 27 kHz (Heele Mod. 3600), powered off main battery. Transducer is mounted topside. Secondary system is 42 kHz, also powered off main battery (Aquasonics Mfg.).

Sonars: Pinger: One 27 kHz, 0.25 w, one ping/sec. rep. rate, powered off main batteries. Avoidance Sonar: One, forward looking transducer (echo sounder) powered off main battery (with recorder & visual display). Directional Antennae: One, bow-mounted, receives from 25 through 40 kHz, five degree wide 90 degree vertical beam.
Marker Buoys: An international orange, 8 in. (20cm) diam. plastic float is manually released to carry 2,000 ft (609m) of 3/16 in. (0.5cm) polypropelene line to the surface. An ice tong is slid down this line which attaches to a 25 ton (22.7t) capacity cable shackled to the hull. A retrieving line is attached to the ice tong.
Jettisonable Components: One manually droppable 180 lb (81.5kg) weight, MBT and trim tanks blowable at operating depth.
Emergency Breathing: Two scuba regulators draw off main ballasting air. Two face masks.

System Readiness: Operational
Classification/Certification: None (applied for ABS)
Support Ship: Ship of opportunity
Owner: Can-Dive Services, Ltd.
250 East Esplanade
No. Vancouver, B.C.
Canada VL7 1A3
Operator: Same as above
Builder: Arctic Marine, Ltd.
No. Vancouver, B.C.
Point-of-Contact: Mr. T.K. Thompson
P.O. Box 91056
West Vancouver, B.C.
Canada V7V 3P2
Telephone: (604) 926-3201

SEA RANGER

CHARACTERISTICS

Length.....17 ft (5.2m)
Beam.....8 ft (2.4m)
Height.....8 ft (2.4m)
Draft.....5 ft (1.5m)
Weight (dry).....9.5 tons (8.6t)
Operating Depth..600 ft (183m)
Collapse Depth...1,800 ft (549m)
Launch Date.....1973

Hatch Diameter.....16.5 in. (42cm)
Life Support Duration.....240 man hrs
Total Power.....43.5 kWh
Speed: Cruise (kts/hrs)..2/10
Max (kts/hrs).....4/5
Crew: Pilot(s).....1
Observer(s).....2
Payload.....2,000 lbs (906kg)
Color.....White above waterline, blue below

Pressure Hull: Cylindrical shape with hemispherical end caps. Composed of 285 Grade C mild steel. Total length is 16 ft (4.9m), diam. 4 ft (1.2m), hull thickness is 0.5 in. (1.3cm).
Power Source: Lead acid batteries in a pressure-resistant pod provide 240 VDC, 180 amp-hr.
Maneuvering Control: Two, stern-mounted (p/s), fixed, reversible propellers and one reversible vertical thruster; both are hydraulically-powered and are driven by a 10 hp electric motor.
Pitch/Trim: Electric motor and hydraulic pump can be moved forward or aft to provide +20 degrees bow angle.
Life Support: Two oxygen flasks of 122 ft^3 (3.4m^3) capacity each at 2,200 psi (154kg/cm^2) are carried, one inside hull (for emergency) and one outside (routine use). O_2 is bled continuously into hull at one l/man/hr. CO_2 scrubber compound is baralyme; 80 lbs (36kg) are carried on each dive. Monitors for O_2, temperature and pressure.
Viewing: Eleven viewports located in conning tower and bow.
Manipulator(s): Two, both located on bow. Largest is 7 ft (2.4m) long, has four degrees-of-freedom, a lifting capacity of 200 lbs (91kg) at full extension and a pincer-type claw of 12 in. (30cm) max. opening. Smaller is 30 in. (76cm) long, has two degrees-of-freedom, linear extension, a static lift capacity of 2,000 lbs (906kg) and a pincer-type claw of 12 in. (30cm) max. opening. Both manipulators are hydraulically-powered and jettisonable.
Lift Point: Consists of a circular steel plate 3.5 in. (8.9cm) ID, 1 in. (2.54cm) thick. The lift point is below the deck fairings and is covered by two metal plates when submerged.
Lighting (underwater): Two, 1,000 w, quartz iodide lights mounted on bow.
Life Jackets: Two, inflatable
Fire Extinguisher: One, dry chemical
Surface Communications: One, self-powered, CW, CB transceiver
Sub-Surface Communications: One underwater telephone, 27 kHz, CW, self-powered, transducer mounted topside. Communications check every 30 minutes, dive aborted if no contact within 60 minutes.
Jettisonable Components: Six droppable weights totaling 600 lbs (272kg). Entire undercarriage is held on by a steel cable which can be cut to release pressure hull and thereby allow it to surface.
Emergency Breathing: Four scuba regulators draw off O_2 tank located external to pressure hull. Approximately 30 minutes duration is provided each user.
Egress Procedure (underwater): Hull may be flooded to allow underwater egress.

System Readiness: Operational
Classification/Certification: None
Support Ship: Ship of opportunity
Owner: Verne Engineering, Inc.
33256 Kelly Rd.
Fraser, Mich. 48026
Operator: Same as above
Builder: Same as above
Point-of-Contact: Kevin Price or James LeBlanc
Verne Engineering, Inc.
(Address same as above)
Telephone: (313) 792-9670

SHELF DIVER

CHARACTERISTICS

Length.....7m (30 ft)
Beam.....1.5m (4.9 ft)
Height.....2.9m (9.5 ft)
Draft.....2.5m (8.2 ft)
Weight (dry).....9t (9.9 tons)
Operating Depth..243m (797 ft)
Collapse Depth...300m (984 ft)
Launch Date.....1968

Hatch Diameter.....60cm (23.6 in.)
Life Support Duration.....216 man hrs
Total Power.....38 kWh
Speed: Cruise (kts/hrs)..2/NA
Max (kts/hrs).....3.5/NA
Crew: Pilot(s).....1
Observer(s).....2
Payload.....80kg (177 lbs)
Color.....Yellow

Pressure Hull: Two cylindrical, steel compartments 0.5 in. (1.3cm) thick, 54 in. (137cm) diameter with hemispherical end caps. The compartments are welded together to form a forward pilot's chamber and an after LOC. A 28 in. (71cm) OD, 19 in. (48cm) high steel conning tower is welded to the pilot's compartment.
Power Source: Lead acid batteries in a pressure resistant cylinder provide 120 V at 275 amp-hrs and 24 V at 243 amp-hrs. An emergency lead acid battery is carried inside the pressure hull which provides 24 V at 93 amp-hrs and 12 V at 35 amp-hrs. Emergency power is for surface and sub-surface communications.
Maneuvering Control: Main forward propulsion is provided by a stern-mounted, fixed, reversible ten hp propeller. Vertical and lateral movement is assisted by two, 1.5 hp bow and stern thrusters.
Pitch/Trim: Sea water can be pumped between two fwd/aft tanks or each tank can be differentially filled to obtain ± angles on the bow.
Life Support: O_2 is carried externally in four tanks which hold a total of 338 ft^3 (9.6m^3) at 2,100 psi (147kg/cm^2). CO_2 is removed by scrubbing cabin air through soda lime (IR 8). Monitors for O_2, CO_2 and pressure; these are measured by the pilot at opportune times.
Viewing: Twenty-three viewports total, 15 are in the pilot's sphere and LOC, eight are in the conning tower.
Manipulator: One, four degrees-of-freedom, hydraulically-powered, 1.5m (4.9 ft) long, parallel jaws-type claw, maximum lift 100kg (221 lbs), not jettisonable.
Lift Points: Two, topside, aft of conning tower. Each consists of an oval-shaped, 7.5cm (3 in.) thick, steel plate which rotates fwd/aft on a steel pin. The attachment point in each plate is a circular hole 60mm (2.4 in.) diameter.
External Lighting: Five units total, four are on the bow and one looks aft. Two are 1,000 w, two are 500 w and one is 250 w, all are quartz iodide.
Life Jackets: Five, inflatable
Distress Flares: One, white color
Surface Lights: One, flashing white, rep. rate once every second, 76cm (30 in.) above the water surface.
Fire Extinguisher: One dry chemical
Emergency Food & Water: Life raft type rations. Five l. (5.3 qts) of water.
Medical Supplies: First aid kit
Surface Communications: One, VHF transceiver, 27 mHz, five channel.
Sub-Surface Communications: One underwater telephone, 27 kHz, two transducers (one topside; one on keel).
Sonars: Scanning sonar (Wesmar): 160 kHz, 1,600 yds (500m) range. Pinger operates on 38 kHz, one month duration. Echo sounder operates on 125 kHz.

Marker Buoy: One, attached to after lift point consists of pressure-resistant cylinder, international orange, 80cm (31 in.) length, 40cm (16 in.) diam. and attached by 800m (2,624 ft) of 4mm (0.15 in.) diam. line to a 2m (6.6 ft) long 15 metric ton (18.4 ton) lift capacity cable. The buoy end of the steel cable is configured to accept a retrieving line which can be slid down the nylon line. Lift capacity of buoy is from 10kg (22 lbs) at operational depth, to 40kg (88 lbs) at surface.
Jettisonable Components: Battery pods are mechanically droppable and weigh 1,659 lbs (750kg) in air.
Emergency Breathing: Five closed-circuit (Fenzy Mfg.) units providing six hours duration for each occupant.
Communications Procedure: Check with surface every 30 minutes, abort dive if no contact established within 45 minutes.

System Readiness: Operational
Classification/Certification: According to French Navy standards
Support Ship: COMMANDANT ROBERT GIRAUD
Owner: French Navy
Operator: Commandant la Division
des Sous-Marins d'Intervention et du Bathyscaphe
du GISMER
83 800 Toulon Naval
France
Builder: Perry Submarine Builders
Riviera Beach, Fla.
Point-of-Contact: Capitaine de Corvette
(Address same as operator)
Telephone: (94) 926300 (Toulon)

SHINKAI

CHARACTERISTICS

Length	16.52m (54.2 ft)
Beam	6.59m (21.6 ft)
Height	6.75m (22.1 ft)
Draft	4.0m (13.1 ft)
Weight (dry)	86t (95 tons)
Operating Depth	600m (1969 ft)
Collapse Depth	1,500m (4,922 ft)
Launch Date	1968
Hatch Diameter	50cm (19.6 in.)
Life Support Duration	192 man hrs
Total Power	200 kWh
Speed: Cruise (kts/hrs)	1.5/10
Max (kts/hrs)	2.24/4.6
Crew: Pilot(s)	3
Observer(s)	1
Payload	300kg (662 lbs
Color	Yellow above waterline, red below waterline

Pressure Hull: Two spheres of NS46 steel 4m (13.1 ft) OD, 36mm (1.4 in.) thickness connected by a 1.45m (4.75 ft) diam. 2.0m (6.6 ft) long cylinder.
Power Source: Lead acid, pressure compensated batteries delivering 100 V x 2000 amp-hr (for six hours).
Maneuvering Control: Main propulsion (fwd/rev) provided by one, stern-mounted 15 hp propeller. Two thrusters, p/s, three hp each, 360 degrees rotatable in the vertical thrusters provide vertical and lateral maneuvering. Static vertical motion obtained through VBTs of 1,630 l. (438 gal) capacity.
Pitch/Trim: Pitch angle of $\pm$5 degrees can be obtained by transfer of sea water fwd/aft.
Life Support: Twelve, 5 l. (0.18 ft^3) capacity each O_2 flasks. CO_2 removed by LiOH. Monitors for O_2 and CO_2 (Drager hand pump type), pressure, temperature and humidity. Dehumidifier.
Viewing: A total of six viewports, five are in the forward sphere and one is in the rescue capsule. Two television cameras, one on bow and one on stern with tilt mechanisms.
Manipulator: One, jettisonable 2.1m (6.9 ft) max. length, six degrees-of-freedom, parallel jaws and orange peel claws, max. lift capacity of 10kg (22 lbs) and max. opening of parallel jaw is 150mm (5.9 in.).
Lift Point(s): Four eye plates topside requiring attachment of a four point lift bridle.
Lighting (underwater): Twenty incandescent lights total, all mounted on bow to illuminate and photograph viewing area. Ten are 100 w flood lights and ten are 500 w narrow diam. projector lights.
Life Jackets: Eight total, all inflatable, four in forward hull and four in emergency capsule.
Surface Lights: Xenon flasher 3.0m (9.8 ft) above waterline, two second rep. rate, powered off main batteries. Duration in excess of one week.
Fire Extinguisher: Two, dry chemical
Emergency Food & Water: Dry food supply providing three days rations/man. Water supply of 15.2 l. (4 gals) carried in forward sphere.
Automatic Deballasting: When vehicle exceeds operating depth by 30m (98 ft) the ballast tanks are automatically blown.
Surface Communications: Two transceivers, one operates on 27 mHz, 0.1 w for routine communications. The second at 158 mHz, 1.0 w for emergency communications.
Sub-Surface Communications: Two underwater telephones, both operate on 8.0875 kHz, one (50 w, 100 VAC) operates off main batteries for routine communications, the second (9 w, 12 VDC) is for emergencies. Communications check every five minutes; of no contact in 15 minutes, dive is aborted.

Sonars: Obstacle avoidance sonar, 200 kHz. Transponder, 50 kHz. Three directional hydrophones (two fwd, one aft) receiving on 50 kHz.
Jettisonable Components: Two lead weights weighing 200kg (442 lbs) and 1,000kg (2,208 lbs) each can be manually released. Manipulator jettisonable: 100kg (220 lbs). Both VBTs and trim tanks can be blown or pumped dry at operating depth.
Emergency Breathing: Each man has two portable emergency breathing (compressed air) devices providing a total of 45 minutes duration.
Egress Procedure (underwater): A 1.75m (5.74 ft) diameter steel sphere is attached to the forward sphere. The crew of four transfers to this sphere and releases it from the submersible's main body. Escape capsule is equipped with O_2 flask, CO_2 scrubber, four life jackets (inflatable) and a flashlight. An inflatable trunk can be filled by compressed air on the surface to provide about 0.7m (2 ft) freeboard about the hatch.

System Readiness: Operational
Classification/Certification: Classed in accordance with Ministry of Transportation guidelines.
Support Ship: M/V OTOME MARU
Owner: Japan Maritime Safety Agency
Hydrographic Department
5-3-1 Tsukiji
Chuo-Ku Tokyo 104
Japan
Operator: Same as above
Builder: Kawasaki Heavy Industries, Ltd.
2-14 Higashikawasaki-cho, Hyogo-Ku
Kobe 650
Japan
Point-of-Contact: Same as operator
Telephone: 03-541-3811
Cable: HYDROOFFICE TOKYO

SKADOC

CHARACTERISTICS

Length.....54m (17.7 ft)
Beam.....1.35m (4.4 ft)
Height.....2.15m (7.1 ft)
Draft.....1.5m (4.9 ft)
Weight (dry).....3t (3.3 tons)
Operating Depth..304m (1,000 ft)
Collapse Depth...914m (3,000 ft)
Launch Date.....1973

Hatch Diameter.....60cm (23.6 in.)
Life Support Duration.....144 man hrs
Total Power.....16 kWh
Speed: Cruise (kts/hrs)..1.5/6
Max (kts/hrs).....5/NA
Crew: Pilot(s).....1
Observer(s).....1
Payload.....200kg (441 lbs)
Color.....Yellow

Pressure Hull: Cylindrical shape with hemispherical end caps, 3.2m (10.5 ft) length; 178cm (70 in.) OD and 11mm (0.4 in.) thick.
Power Source: Lead acid batteries (16) in pressure-resistant pods providing 24 VDC at 180 amp-hr.
Maneuvering Control: Static: One VBT of 202kg (447 lbs) capacity, pumped to fill and empty. Dynamic: One, stern-mounted, reversible screw-type propeller trainable 45 degrees p/s. One hydraulic jet thruster rotatable 360 degrees in the vertical mounted on bow to assist lateral motion.
Life Support: Two, ten l. (2.6 gal) capacity O_2 flasks carried inside pressure hull and continuously bled into cabin. CO_2 is removed by scrubbing through soda sorb. Monitors for O_2, CO_2, temperature, humidity, pressure. Check of each property every 15 minutes.
Viewing: Eight viewports total, four in bow and four girdling conning tower. TV with recorder inside pressure hull.
Lift Points: Standard metal lift hook attached to after side of conning tower by a rigid, rotatable metal arm. The lift hook is horizontal during a dive and raised to the vertical for launch/retrieval.
External Lighting: Two, 1,000 w, quartz iodide lights mounted on bow.
Life Jackets: Two, inflatable
Surface Lights: One, self-powered, flashing blue light, 70cm (28 in.) above water surface, four to five day duration, one flash/second.
Fire Extinguisher: One, dry chemical
Medical Supplies: First aid kit
Surface Communications: One, VHF, self-powered radio transceiver, range of 15km (8nm).
Sub-Surface Communications: One underwater telephone, 27 kHz, self-powered, CW (Spiro Technique Mfg.).
Sonars: Scanning sonar (Wesmar 120SS). Pinger: One, self-powered, 27 kHz, one ping/second, 30 day duration (Hydro Prod. Mfg.).
Marker Buoy: A stainless steel cylinder with hemispherical end caps, 20cm (7.9 in.) diam., 30cm (11.8 in.) long attached to 250m (820 ft) of 4mm (0.2 in.) diam. nylon line, mechanically released.
Jettisonable Components: One 75kg (166 lbs) weight, mechanically dropped. Positive buoyancy of 502kg (1,109 lbs) can be obtained at operating depth by inflating a balloon held inside a parachute atop the vehicle.
Emergency Breathing: Two, (Drager Mfg.) closed-circuit units provide each occupant the capability of breathing directly through CO_2 scrubber if power fails. One set of scuba tanks, regulator, face mask, flippers and wet suit in LOC.
Egress Procedure: One man can exit through lockout compartment.
Communications Procedure: Check with surface every 15 minutes, dive is not aborted if communications fail.

System Readiness: Operational
Classification/Certification: None, will apply for Lloyds classification.
Owner: Skadoc Submersible Systems
Damstraat 104
Yerseke
Netherlands
Operator: Same as above
Builder: Same as above
Point-of-Contact: H.H. Lok
Address same as above
Telephone: 01131-1636
Cable: Smit/Tak Int. Salvage Co.
Rotterdam
Boom p.

SNOOPER

CHARACTERISTICS

Length.....14.5 ft (4.4m)
Beam.....4.1 ft (1.3m)
Height.....7 ft (2.1m)
Draft.....5 ft (1.5m)
Weight (dry).....2.25 tons (2t)
Operating Depth..1,000 ft (304m)
Collapse Depth...2,100 ft (640m)
Launch Date.....1969

Hatch Diameter.....20.5 in. (52cm)
Life Support Duration.....48 man hrs
Total Power.....9.7 kWh
Speed: Cruise (kts/hrs)..1/5
Max (kts/hrs).....3/3
Crew: Pilot(s).....1
Observer(s).....1
Payload.....200 lbs (91kg)
Color.....White

Pressure Hull: Cylindrical shape, hemispherical end caps, composed of mild (A-212) steel 0.5 in. (1.3cm) thick 36 in. (91cm) OD on main body and 24 in. (61cm) OD on conning tower. Total length of main pressure hull, 8.3 ft (2.5m); conning tower 2.2 ft (0.7m).
Power Source: Lead acid batteries carried in two, pressure-resistant, droppable pods p/s amidships. Each pod (bank) delivers 200 amp-hrs at 24 V.
Maneuvering Control: One stern-mounted, reversible propeller driven by a three hp electric motor and capable of rotating 110 degrees p/s in the horizontal plane.
Pitch/Trim: A 40 lb (18kg) lead weight is moved fwd/aft on an endless chain by an electric motor to provide a pitch angle of ± 4 degrees.
Life Support: A total of 40 ft^3 ($1.1m^3$) of oxygen is carried in the pressure hull at 1,800 psi ($126kg/cm^2$). CO_2 is removed by scrubbing through baralyme. Monitor for O_2. Scrubber powered off main battery. O_2 added as indicated by O_2 monitor.
Viewing: Ten viewports, four in conning tower, one in hatch cover, one in stern and four on bow.
Manipulator: One, three degrees-of-freedom with linear extension, non-jettisonable, capable of 30 lb (13.6kg) lift, scissors-type claw.
Lift Point: One, 0.75 in. (1.9cm) thick steel plate is located forward and one aft of the conning tower; each plate has two circular penetrations of 1 7/8 in. (4.6cm) and 0.75 in. (1.9cm) diameter. Any one of these four attachment points can support entire vehicle weight.
Lighting (underwater): A total of six, 250 w each, incandescent lights are mounted under the brow (three port and three starboard).
Life Jackets: Two Stenkie Hoods, inflatable.
Surface Communications: CB transceiver, 5 w, self-powered, hatch must be opened to operate.
Sub-Surface Communications: One underwater telephone operates on 8.0875 kHz and draws power from main batteries (Gen. Oceanographics, Mfg.). Contact established with surface every 30 minutes, but dive is not aborted if unable to establish communications.
Marker Buoys: A yellow, egg-shaped foam float, 1 ft (31cm) long and 7 in. (18cm) wide can be manually released and is held to the vehicle by a 1/8 in. (0.3cm) polypropalene line.
Jettisonable Components: One, 140 lb (63kg) steel weight and two battery pods weighing 600 lbs (272kg) each.
Emergency Breathing: Two scuba regulators draw off MBT air supply. Duration depends upon amount of air in tanks.
Egress Procedure (underwater): Hull can be flooded through a 2 in. (5cm) diam. penetration; occupants may exit wearing Stenkie hoods.

System Readiness: Operational
Classification/Certification: None
Support Ship: M/V MOTHER GOOSE
Owner: Undersea Graphics, Inc.
5436 Sharynne Lane
Torrance, Ca. 90505
Operator: Same as above
Builder: Same as above
Point-of-Contact: Mr. Donald Siverts or Mr. Paul Gamroth
(Address same as above)
Telephone: (213) 379-7271

TAURUS

CHARACTERISTICS

Length.....34 ft (10.4m)	Hatch Diameter.....35.5 x 38 in. (90 x 96.5cm) DTC
Beam.....13 ft (4.0m)	Life Support Duration.....27 in. (69cm) Pilots'
Height.....12 ft (3.7m)	Total Power.....500 man hrs
Draft.....NA	Speed: Cruise (kts/hrs)..NA
Weight (dry).....26.5 tons (24t)	Max (kts/hrs).....3/NA
Operating Depth..2,000 ft (610m)	Crew: Pilot(s).....2
Collapse Depth...NA	Observer(s).....NA
Launch Date.....Under construction	Payload.....2 tons (1.8t)
	Color.....NA

Pressure Hull: Two sections composed of A516 Grade 70 steel. Forward (command or pilot's) section is cylindrical with hemispherical end caps, 72 in. (183cm) diam., 80 in. (203cm) total length. The after Dry Transfer Chamber (DTC) is bolted to the command section, it is a sphere 84 in. (213.4cm) in diameter. A 27 in. (68.6cm) opening is between both sections and can be sealed by a hatch when the DTC is pressurized.
Power Source: Lead acid batteries, pressure compensated providing 120 V at 1,000 amp-hrs (eight hr rate) and 24 V and 12 V at 300 amp-hrs. A 20 amp-hr (eight hr rate) 12 V gel cell is carried inside the pressure hull for emergency power.
Maneuvering Control: Four thrusters, all five hp with Kort nozzles. Two are mounted p/s at the center of gravity, these are trainable in the vertical plane from 90 degrees up to 90 degrees down. Two are mounted on the stern and one trainable 90 degrees p/s to provide main and lateral propulsion.
Pitch/Trim: A 1,000 lb (452kg) lead weight can be moved forward or aft to provide ±12 degrees bow angle. Two "hard" tanks forward and one aft are for transfer of water to obtain maximum bow angles of ±25 degrees. Total volume capacity of these tanks is 2,800 lbs (1,266kg).
Life Support: O_2 carried externally. CO_2 removed by LiOH and/or soda sorb. Monitors for O_2, CO_2, temperature, pressure, humidity.
Viewing: Acrylic plastic bow dome 36 in. (91cm) ID. Five, 5 in. (12.7cm) ID viewports girdle the conning tower; one 6 in. (15.2cm) ID viewport in the DTC hatch covers. External TV camera and video recorder.
Manipulators: Two, one heavy duty and one articulated.
Lift Point: One metal padeye located immediately aft of conning tower fairing with a circular opening.
External Lighting: Three, 1,000 w, incandescent for viewing. Two, 250 w, mercury vapor lights for TV.
Surface Communications: VHF FM transceiver.
Sub-Surface Communications: Underwater telephone.
Sonars: Scanning sonar (Wesmar SS1405), 160 kHz, 1,600 ft (488m) range, trainable +four degrees to -90 degrees from the horizontal, 360 degree lateral coverage. Echo sounder, Doppler sonar, directional antennae.
Jettisonable Components: A 1,000 lb (452kg) lead weight is mechanically droppable. Thrusters and manipulator claws are also jettisonable.
Emergency Breathing: Closed-circuit units for each occupant.

System Readiness: Vehicle is presently at International Hydrodynamics, Ltd., under construction, schedule completion is October 1976. Vehicle is designed for dry transfer of personnel and equipment.
Classification/Certification: ABS applied.
Support Ship: NA

Owner: Hyco Subsea Ltd.
P.O. Box 1059
Station "A"
Vancouver, B.C. V6C 2P1
Canada
Operator: Same as above
Builder: International Hydrodynamics, Ltd.
No. Vancouver, B.C.
Canada
Point-of-Contact: Michael D. Macdonald
(Address same as owner)
Telephone: (604) 681-0346
(604) 688-8607
Telex: 04-55465

TRIESTE II

CHARACTERISTICS

Length.....78 ft 6 5/8 in. (23.9m)
86 ft 3 5/8 in. (26.5m) (with bow - frame)
15 ft 3 1/4 in. (4.7m) (hull only)
Beam.....18.75 ft (5.7m) (between motors)
Height.....26 ft 11 in. (8.2m)
Draft.....10 ft 8 in. (3.3m) (without gas and shot)
18 ft 8 in. (5.7m) (with gas and shot)
Weight.....95 tons (86t) (without gas and shot)
Operating Depth...20,000 ft (6,096m)
Collapse Depth....31,793 ft (9,691m)
Launch Date.....1964
New sphere 1975

Hatch Diameter.....16.9 in. (42.9cm)
Life Support Duration....139.5 man hrs
Total Power.....NA
Speed: Cruise (kts/hrs).1.5/11.9
Max (kts/hrs)....NA
Crew: Pilot(s).....2
Observer(s).....1
Payload.....NA
Color.....White

Pressure Hull: Spherical shape composed of HY 120 steel, 7 ft (2.1m) ID, 4 in. (10.1cm) nominal thickness
Power Source: Silver zinc batteries, pressure compensated, providing 120 VDC at 952 amp-hrs (propulsion) and 24 VDC at 5,000 amp-hrs (auxiliary). Emergency power provided by a silver zinc battery inside the pressure hull, 24 VDC at 200 amp-hrs, operates ballast control, communications, propulsion control, alarm panel, CO_2 scrubbers, pressure/depth systems, echo sounder, ante-chamber blow system, battery monitor alarm, internal lights, emergency/tracking pinger, atmospheric monitors.
Maneuvering Control: Main propulsion is provided by three, 6.5 hp (ea.) stern-mounted, reversible propellers (with kort nozzels). A 6.5 hp, reversible bow thruster assists in lateral maneuvering.
Life Support: O_2 carried inside hull in three flasks (two for routine; one for emergency), the volume of each flask is 730 $in.^3$ (11,965 cm^3) and each is charged to 2,250 psi (158kg/cm^2). CO_2 is removed by scrubbing with LiOH. O_2, CO_2, temperature, humidity and pressure are monitored continuously and recorded every 30 minutes. O_2 and CO_2 monitors are connected to an aural (buzzer) and visual (red light) alarm. There are three O_2 monitors and two CO_2 monitors.
Viewing: One major viewport looks forward and down. Two smaller viewports, one looks directly aft and one is in the hatch cover. Three external TVs, all on pan and tilt mechanisms, one video recorder. Provisions are available for a fourth camera.
Manipulators: One, hydraulically-powered, four degrees-of-freedom with wrist rotate, parallel jaws type claw, jettisonable.
Lift Point: Not feasible to consider as an underwater retrieval factor.
External Lighting: Eight gas discharge lights, four are thallium iodide, 400 watts each; four are multivapor at 400 watts each. Ten quartz iodide, eight are 300 watts and two are 500 watts.
Life Jackets: Three, inflatable
Radar Reflector: One, permanently-mounted, 12 ft (3.7m) above water level, corner reflector, solid.

Surface Lights: Two, flashing white, 7 ft (2.1m) above water line, 300 watt-seconds each, pressure-activated, three flashes per minute.
Fire Extinguisher: One, carbon dioxide
Emergency Food & Water: Water from atmospheric cooler/dehumidifier is potable.
Automatic Deballasting: Twenty eight tons (25t) of shot, manipulator, trail ball will automatically be jettisoned 33 hours after submerging.
Surface Communications: One radio transceiver, VHF (143.7 mHz), 5 watts. Optional mode provides homing beacon (tone modulated at 800 Hz).
Sub-Surface Communications: One, underwater telephone, 8.0875 kHz, 400 watts, single side band, CW.
Surface Homing Devices: The radio transceiver includes a beacon option.
Sonars: Two CTFM scanning sonars (Ametek Straza Mod. 500) modified to provide two external systems with one internal display, 87 to 72 kHz, 360 degree pan (manual control). One pinger (Sperry Mfg.), 32 kHz tracking frequency, 37 kHz emergency frequency, tracking: one ping/sec continuous, emergency: one ping/sec/eight seconds; 24 seconds silence, 96 hrs duration. Transponder (Sperry Mfg.), receives on 7 kHz responds on 12.5, 13 and 17.5 kHz (selectable). Echo sounder looks downward, strip chart recorder, 50 kHz, 2,400 ft (731m) range. Doppler sonar navigator. Transponder interrogator (control in sphere), transmits on 7 kHz; receives on 10 channels 12.5 kHz through 17 kHz at 500 kHz increments.
Jettisonable Components: Shot, manipulator, trail rope winch. Scientific packages (two each) can also be jettisoned when carried.
Emergency Breathing: Three full facemasks, closed-circuit, draws off emergency oxygen and exhales through two LiOH cannisters (60 man-hrs each scrubbing capacity). System is man-powered, 120 man-hrs breathing duration.
Communications Procedure: Surface communications checked every 30 minutes; if no contact is established the dive is aborted.

System Readiness: Operational
Classification/Certification: U.S. Navy certified
Support Ship: USS Pt. LOMA (AGDS-2)
Owner: U.S. Navy
Operator: Submarine Development Group One
San Diego, Ca.
Builder: Mare Island Naval Shipyard
Point-of-Contact: Commander
Submarine Development Group One
San Diego, Ca.
Telephone: (714) 225-6583

URF

CHARACTERISTICS

Length.....13.5m (44.3 ft)	Hatch Diameter.....600mm (24 in.)
Beam.....4.3m (14.1 ft)	Life Support Duration.....980 man hrs
Height.....3.9m (12.8 ft)	Total Power.....22 kWh
Draft.....2.9m (9.5 ft)	Speed: Cruise (kts/hrs)..2/10
Weight (dry).....50t (55 tons)	Max (kts/hrs).....3/5
Operating Depth..460m (1,509 ft)	Crew: Pilot(s).....5
Collapse Depth...900m (2,952 ft)	Rescuees.....25
Launch Date.....1977 (under construction)	Payload.....2.2t (2 tons)
	Color.....White with international orange sail and rudder/ dive planes

Pressure Hull: Four compartments: 1) a cylindrical compartment for rescuees and machinery, 2.0m (6.6 ft) ID and 10.9m (35.8 ft) long composed of HY-130 steel; 2) a spherical pilot's compartment 1.73m (5.7 ft) ID; 3) a spherical rescue compartment 2.8m (9.2 ft) ID located between the pilot's sphere and the cylinder and 4) a spherical diver's compartment 2.0m (6.6 ft) ID located aft. The last three compartments are composed of mild steel.
Power Source: A total of 64, 2.3 V lead acid batteries rated at 1,500 amp-hrs are located within a pressure-compensated container beneath the rescue cylinder.
Maneuvering Control: Static: Four MBTs of $0.8m^3$ ($28 ft^3$) each and one VBT of $0.7m^3$ ($25 ft^3$) capacity. Dynamic: Two main thrusters mounted p/s forward over the rescue skirt are fixed, reversible, six hp and fitted with a kort nozzle. Two, two hp, horizontal and two vertical thrusters are located forward and aft and ducted within the fairing.
Pitch/Trim: Bow angles of $\pm$30 degrees may be obtained by transferring 24.9 l. (6.6 gal) of mercury forward or aft. Roll angles of $\pm$45 degrees can be obtained by readjusting two, 70kg (154 lbs) each weights to different locations along the vehicle's bulkheads.
Life Support: A total of 26, 50 l. (13 gal) capacity each, flasks are located external to the hull, three carry O_2; five carry H_e and 18 carry H_eO_2 all at 200 bars (2,900 psi) pressure. CO_2 is removed by scrubbing with soda lime. Monitors for O_2, temperature and pressure. Drager hand-pump devices are carried as back-up. Heaters are supplied in diver's compartment and silica gel is distributed to control humidity. Life support by compartment: Pilot's sphere - 168 man hrs; Machinery sphere - 84 man hrs; Diver's sphere - 178 man hrs; Rescue cylinder - 550 man hrs.
Viewing: Eight viewports total. Three in conning tower (small diam.). The remaining five are 550mm (22 in.) OD and 170mm (6.7 in.) ID and are located as follows: three in pilot's sphere, one in hatch cover of mating skirt and one in lower diver's sphere hatch cover. A television camera is situated to view the area within and below the mating skirt.
Manipulator: One, jettisonable, with three degrees-of-freedom and linear extension. This is not a multi-purpose manipulator, it is only used to attach a down-haul line to the stricken vehicle's hatch cover in order to mate.
Lift Points: Two, steel, circular, 65mm (2.6 in.) ID, 92mm (3.6 in.) thick, located forward and aft. The forward point can sustain 35t (38.5 tons), the after point 18t (19.8 tons).
External Lighting: Nine lights, quartz iodide, 250 and 1,000 w all mounted forward.
Surface Lights: One, white, non-flashing mounted on the rudder some 800mm (31.5 in.) above the water surface and is powered from the main batteries.

Fire Extinguisher: One in pilot's sphere, dry chemical; three in auxiliary compartment, dry chemical.
Emergency Food & Water: The following quantities of fresh water are carried: 8 l. (8.5 qts) in pilot's sphere; 45 l. (48 qts) in rescue cylinder; 4 l. (4.2 qts) in auxiliary compartment; 8 l. (8.5 qts) in diver's sphere.
Surface Communications: One VHF transceiver, powered off the main batteries, 100-156 mHz, 5-6nm (9-11 km) range. Can be used as surface emergency beacon.
Sub-Surface Communications: One underwater telephone, with two transducers (one fwd; one aft), 8.0875 kHz, CW, 100 w, operates off main batteries. Diver-to-sub communications is by hardwire. Powered intercom throughout sub and sound-powered system for backup.
Surface Homing Devices: One, frequency of 100-156 mHz.
Sonars: Scanning sonar (Straza CTFM Mod. 500), 87-72 kHz, can also serve as directional antennae from 36.5 to 37.5 kHz. Pingers: One, 37 kHz, self-powered, 30 days duration, one second rep. rate, pilot-activated.
Jettisonable Components: Two tons (2t) of iron shot, roll adjustment weights, manipulator and main thrusters. MBTs and VBT can be blown or pumped (VBT only) at operational depth.
Emergency Breathing: Systems in the diver's and auxiliary compartment draw off main ballasting air, approximately 36 man hrs duration. If main power lost in CO_2 scrubber, individual systems can be donned that manually draw air through the scrubbing system.

System Readiness: Under construction, ready by late 1977.
Classification/Certification: Built to Kockums standards.
Owner: Royal Swedish Navy
Operator: Same as owner
Builder: Kockums
Fack, S-201
10 Malmo 1
Sweden
Point-of-Contact: Capt. Johan Onnrrmark
Storovagen 13
13200 Saltsgo-boo
Stockholm
Sweden

VOL L1

CHARACTERISTICS

Length.....33.3 ft (10.1m)
Beam.....10.8 ft (3.3m)
Height.....10.8 ft (3.3m)
Draft.....5.3 ft (1.6m)
Weight (dry).....16 tons (14.5t)
Operating Depth..1,200 ft (366m)
Collapse Depth...1,800 ft (549m)
Launch Date.....1973

Pilot's comp. 23 in. (58cm)
Hatch Diameter.....LOC 28 in. (71cm)
Life Support Duration.....35 man days
Total Power.....46.7 kWh
Speed: Cruise (kts/hrs)..2/NA
Max (kts/hrs).....3.4/NA
Crew: Pilot(s).....1
Observer(s).....4
Payload.....600 lbs (272kg)
Color.....White

Pressure Hull: Two cylinders joined to form a forward (pilot's) compartment and an after LOC. Both sections are composed of A5376RA steel, the pilot's compartment is 1.5 ft (1.4m) OD and 8.8 ft (2.7m) long, the LOC is 4.5 ft (1.4m) OD and 6.6 ft (2.0m) long. Access from one compartment to the other is through a 2 ft (0.6m) diameter hatch.
Power Source: Lead acid batteries in two pressure-resistant pods. Batteries are arranged to provide four banks of 24 V and 120 V, each four-bank system totals 324 amp-hr.
Maneuvering Control: Main propulsion is from a fixed, stern-mounted, screw-type propeller powered by a ten hp motor. Lateral movement is provided by two thrusters one mounted forward and one aft. Vertical movement is provided by a forward and aft vertical thruster. Dive planes assist in dynamic pitch control.
Pitch/Trim: Internal tanks forward and aft can be differentially filled to obtain up/down bow angles.
Life Support: O_2 is carried in three external flasks each holding 332 ft^3 (9.3m^3) at 3,000 psi (210kg/cm^2). CO_2 is removed by scrubbing through LiOH in the pilot's compartment and through soda sorb in the LOC. Pilot's compartment contains monitors for O_2, CO_2, CO, temperature, humidity and pressure; these are monitored every 15 minutes. LOC carries monitors for O_2, temperature and pressure.
Viewing: Six viewports girdle the conning tower and one is in the hatch cover. LOC has viewports in the lockout hatch covers and one on each side of the compartment. A 34 in. (86cm) diameter acrylic plastic dome is in the bow. Two television systems, one is forward on pan and tilt mechanism; the second is in the LOC and can be carried out by the divers or used from inside the LOC.
Manipulator: One, five degrees-of-freedom, lift capacity of 200 lbs (90.4t) at maximum extension, scissors and parallel jaws-type claws.
Lift Points: There are three points (front frame, pilot's compartment, LOC) where a standard shackle can be attached to provide 16 tons (14.5t) lift.
External Lighting: Six units total, five mounted forward and one mounted aft on the LOC. All are quartz iodide and 500 w each.
Life Jackets: Five inflatable
Surface Light: One flashing light, blue/white, 1 ft (0.3m) above water surface, self-powered.
Fire Extinguisher: Two, dry chemical
Emergency Food & Water: Seven gallons (26.5 l.) of water are carried and food blocks to provide 35 man-days duration.
Medical Supplies: First aid kit
Surface Communications: VHF transceiver (Storno CQM6R), ten w marine band, line of sight range, three channels (156.55, 156.80, 157.65 mHz), main and emergency power.

Sub-Surface Communications: One (Subcom Sys. Mfg.), 10 or 27 kHz, transducers mounted atop vehicle, operates off main or emergency power supply.
Sonars: Scanning Sonar (Wesmar SS130), 360 degree scan, 160 kHz. Pinger mode built into underwater telephone (Subcom Sys. Mfg.), 10 or 27 kHz, one pulse/second rep. rate, two transducers. Directional Antennae (Helle Mfg.), receives from 25 to 40 kHz. Transponder carried (AMF or VOL Mfg.), frequency and characteristics vary according to task.
Marker Buoy: One, spherical shape, 10 in. (25.4cm) diameter, hydraulically-released and attached to 2,000 ft (610m) of line.
Jettisonable Components: Manipulator and battery pods can be jettisoned by activating an emergency hand pump. Total weight: 6,909 lbs (3,130kg).
Emergency Breathing: Five regulators are available for emergency breathing which draw off the MBT air supply.
Communications Procedure: Check with surface every 15 minutes; abort dive if communications are not established within 30 minutes.

System Readiness: Operational
Classification/Certification: ABS
Support Ship: VICKERS VIKING
Owner: Vickers Oceanics, Ltd.
P.O. Box 8
Barrow-in-Furness
Cumbria
England LA14 1AD
Operator: Vickers Oceanics, Ltd.
Old Docks, Leith
Edinburgh
Scotland
Builder: Perry Submarine Builders, Inc.
Riviera Beach, Florida
Point-of-Contact: Base Duty Officer
Address same as operator
Telephone: 031 554 0676 (Leith)
Telex: 72248

4.0 SEARCH/RETRIEVAL ASSETS

In this section are capabilities, other than manned submersibles themselves, which may be used to locate and help retrieve a manned vehicle which cannot surface. There is, according to the U.S. Navy, no other feasible method of bringing the occupants of a submersible to the surface except to retrieve the vehicle in its entirety. The Navy philosophy assumes that all other self-help assets (e.g., droppable ballast, lockout capability) have been considered or employed but the occupants remain entrapped. Retrieval, for all practical purposes, means attaching a line to the submersible and hauling it up to the surface.

Search assets are herein defined as those devices which can be employed to either locate the submersible underwater, or provide the rescuers a capability to assess the submersible's condition and the nature of its entrapment. This assessment capability may be provided by photography (cine or still camera), by television or by visual observations from divers. In some instances the search asset may also provide the capability for attaching a retrieving line.

It is extremely difficult to define the limits or boundaries of this category. For example, the Naval Ordnance Laboratory (NOL) device that was used in retrieval of JOHNSON-SEA-LINK I was an "eleventh hour" approach which proved successful. Prior to this incident, the NOL device, which was designed for the specific purpose of hardware inspection in the Gulf Stream, was not considered a submersible search/retrieval asset in any public Naval document; it is still not included in a recent Navy Laboratory inventory of search/retrieval assets that post-dates the JOHNSON-SEA-LINK I tragedy. Likewise, there are innumerable

other devices and capabilities which, at the last moment, may serve as the means of retrieval. Therefore, a practical limit must be placed somewhere, or otherwise a listing of every grapnel hook, diver, dredge, and underwater camera and television unit in the world must be included. The limit, therefore, was arbitrarily drawn at: 1) a minimum 600 ft (183m) depth capability; 2) a real-time viewing capability offered through television or the human eye and 3) a means to control and maneuver the television platform in the x, y and z axis. The towed devices are included in this category because they offer multi-instrumented search capabilities with long-duration and relatively high speed.

Availability - There is only one known search/retrieval asset that is maintained in a ready-to-go condition at all times: the U.S. Navy's DEEP DRONE. When not undergoing training or evaluation dives, DEEP DRONE is maintained and operated by a full-time crew that can be mobilized on call. This unit is located at Camp Springs, Maryland.

Commercial search/retrieval assets are not purchased and maintained to stand by and wait for an emergency application. They are assets which were built to be used as frequently as possible for a variety of tasks. Their capability as a submersible rescuer is incidental to their capability as an underwater work platform. To economically justify their existence, they must be employed, and this employment can be anywhere at any particular time; hopefully (from a commercial owner's point of view), they are always on long-term employment. Consequently, it is impractical to state that vehicle "x" can be mobilized in a certain amount of hours or days and will require a specific amount of time to be shipped from its home port to the emergency site. The only way a meaningful

emergency response time can be derived is to maintain a weekly, or even daily, check on a particular vehicle's status and location. For these reasons, availability data is not included in the following discussions other than to note, under "Remarks," that the device or capability is under design or under construction. All other assets can be assumed operational unless otherwise stated.

The Harbor Branch Foundation's CORD is one possible exception to the foregoing statement. CORD was designed and built for submersible rescue (although it has been tested as a bottom survey platform). When it is considered fully operational by the Foundation, CORD will be maintained for rescue of the JOHNSON-SEA-LINK I and II at any time they are operating. Considering the great emphasis placed on their own operational safety and the demonstrated willingness to become involved in diving safety overall, it is more than likely that CORD, and all Harbor Branch Foundation assets, would be immediately available to any submersible where the occupants are in extremis.

4.1 Unmanned Self-Propelled and Towed Devices

Both the self-propelled and towed devices are linked to a surface platform by a cable. The cable, in all but one instance (TROV), supplies electrical power to the device's propulsion system and instruments. It also serves to carry control commands to the device's electrical components and to transfer data from the device to the surface. For clarification, unmanned devices are categorized herein as: 1) Towed systems and 2) Self-propelled, tethered systems; these are defined and discussed in the following sections.

4.1.1 Towed Systems

Towed systems include all systems that rely upon a moving surface platform for propulsion. They are employed by being towed at some near-constant height (altitude) off the bottom. Power for these systems is generally supplied from the surface platform. Maneuverability is provided by the surface platform and a winch operator; hence, they are limited to two translational motions: thrust (forward motion) and heave (up/down motion), and one rotational motion: yaw (obtained by maneuvering the support craft).

Excluded from this category are towed systems which are dragged along the bottom. From a search/retrieval aspect, such systems, owing to their lack of maneuverability, may further compound an entanglement situation by becoming fouled themselves. Also excluded are systems which are deployed from a stationary (anchored) surface platform and thus rely upon the winch and cable for up/down motion. These latter systems, owing to their lack of maneuverability, are not considered as viable candidates for submersible search/retrieval missions where time is of the essence as human life is jeopardized.

Ten towed systems have been identified worldwide which can be considered as potential candidates for submersible search/identification missions. These are listed in Table 4.1. Only two of these devices, DSS-125 and SEA PROBE, are owned by private industry. The remainder are owned by the U.S. Navy (DEEP TOW, NRL System, TELEPROBE, STOVE) and academic/research activities (BATFISH, CRAB, RUFAS II, S^3).

All of the towed systems listed have closed circuit television and, except for CRAB and DSS-125, some form of scanning sonar to provide a relatively long

TABLE 4.1 TOWED SYSTEMS

NAME	OWNER	OPERATING DEPTH (ft/m)	DRY WEIGHT (lbs/kg)	MAX SPEED (kts/ km/hr)	POWER REQUIRE-MENTS	WORK EQUIPMENT	REMARKS
BATFISH	Bedford Inst. of Oceanology Halifax, N.S.	650 198	156 71	5 9	110 VAC, 6 Hz	TV, still camera, side scan sonar	Operational
CRAB	Inst. of Oceanology USSR, Moscow	13,123 4,000	1,548 702	NA	Lead acid batteries	TV, manipulator	Employed by drifting; can be placed on bottom to sample or observe.
DEEP TOW	Marine Physics Lab. San Diego, Ca.	20,000 6,096	2,000 907	1.5 2.8		TV, still camera, magnetometer, side scan sonar, sub-bottom profiler, echo sounder, diff. pressure gauge	Operational
DSS-125	Hydro Products San Diego, Ca.	20,000 6,096	5,100 2,313	1.5 2.8	115 VAC, 60 Hz, 20 amps, or 220 VAC, 50 Hz, 10 amps	TV, still camera	
NRL System	Naval Research Lab. Washington, D.C.	20,000 6,096	2,200 998	3 5.6	20 amp-hr, ni-cad batteries, 28 VDC	TV, still cameras, magnetometer, side scan sonar, water sampler, sub-bottom profiler	No dedicated support ship; would require at least 48 hrs to mobilize.
RUFAS II	National Marine Fisheries Services Pascagoula, Miss.	2,400 731	1,000 453	6 5.1	115 VAC, 12 VDC, 4 kw total	TV, still camera, scanning sonar	Undergoing tests; planned operational by end of 1976
S^3	Univ. of Georgia Athens, Ga.	6,000 1,829	700 317	1 1.8	NA	TV, side scan sonar, magnetometer, sub-bottom profiler, dredge	Has terrain following guidance system. Requires 30 days to become operational.
SEA PROBE*	Alcoa Marine Corp. Washington, D.C.	10,000 3,048	--	0.5 0.9	NA	TV (2 ea), still camera (35mm), side scan scanning sonar	Two weeks to mobilize. Can lift 200 tons (181t) from 6,000 ft (1829m) depth.

TABLE 4.1 TOWED SYSTEMS (Continued)

NAME	OWNER	OPERATING DEPTH (ft/m)	DRY WEIGHT (lbs/kg)	MAX SPEED (kts/ km/hr)	POWER REQUIRE-MENTS	WORK EQUIPMENT	REMARKS
STOVE	Submarine Development Group One, San Diego, Ca.	20,000 6,096	NA	NA	Lead acid batteries	Still cameras, side scan sonar	Under development in April 1976; status unknown
TELEPROBE	NAVOCEANO Suitland, Md.	20,000 6,096	3,500 1,588	3 5.6	50 amp, 120 V regulated power	TV, side scan sonar, magnetometer, stereo-photography	Operational; 24 hours mobilization

*SEA PROBE consists of a surface ship, drill string and equipment pods; the latter can only operate from its specifically-designed ship.

range acoustic search capability. The potential effectiveness of these systems, particularly those with depth capabilities exceeding 10,000 feet (3,048m), in locating a stricken submersible in time to affect rescue is speculative. While mobilization time (that period required to load the system components on a truck) may be 24 or 48 hours with maximum effort, there are other factors which govern at-sea employment. The major factor is that of locating a surface ship that has a suitable (and working) winch which can accommodate the power/life cable and a system for handling the device over-the-side. Ships of the U.S. Navy AGS and AGOR-types are suitable, but they do not remain on standby awaiting the call for rescue. Furthermore, they may be operating in areas far distant from the scene of the emergency. In Section 5.6.1 the average submersible life support duration was calculated at 85 hours or 3.5 days per occupant. Under the best conditions, 24 hours would be required to merely mobilize the deeper systems, leaving the occupants 2.5 days of life support. Considering that the AGS and AGOR-type ships can make approximately 13 knots (24 km/hr) top speed, at any given time, at least 24 hours must be allowed to reach a suitable rendezvous point with the towed system. Then, the system must be loaded aboard, installed, transit made to the emergency area, and then the system be deployed to begin searching for the lost vehicle; all within 2.5 days. If the search is successful, then retrieval efforts begin. It is beyond the scope of this survey to conduct a statistical analysis of the liklihood for successful search of a submersible within the life support duration provided by contemporary vehicles. From a practical point of view, the occupants have little or no chance for timely rescue if they must rely upon search and location before retrieval efforts can begin.

4.1.2 Self-Propelled, Tethered Systems

This category includes devices that have their own means of propulsion, but are connected by cable to a surface platform. These systems generally obtain their power from the surface platform and provide a real-time, televised picture to the surface operator. Not included in this category are self-propelled, free-swimming devices, such as the Applied Physics Laboratory's (University of Washington) Unmanned Arctic Research Submersible (UARS). While this latter system provides a number of advantages to certain undersea tasks, search/retrieval of submersibles is not considered as one of their best applications, primarily because they do not supply real-time visual data to the surface and they lack the maneuverability of the tethered systems.

The surge in commercial and academic development and production of unmanned, tethered, self-propelled vehicles within the last year has been phenomenal. Since January 1975, 22 of these vehicles have been constructed or announcements have been made of their development; prior to this date only eight were reported in the open literature and five of these were military developments.

A list of 33 tethered, self-propelled vehicles is presented in Table 4.2. These are vehicles which are reportedly operating or are under construction. The major impetus behind commercial development of these vehicles is the increased need of the offshore oil and gas industry for *in situ* inspection and documentation of undersea hardware. Company sales brochures and technical papers on unmanned devices uniformly introduce their product as a safer, more economical alternative to manned submersibles and the ambient diver. Similar to the tremendous surge of manned submersible development in the sixties, unmanned devices of the seventies reflect a variety of ideas concerning the best design and operational approach.

TABLE 4.2 UNMANNED, SELF-PROPELLED, TETHERED VEHICLES

VEHICLE	DEPTH (Feet/ Meters)	BUILDER	OPERATOR	STATUS
ANGUS	984/ 300	Heriot-Watt University Edinburgh, Scotland	Same	Inactive at present
ANGUS 002	NA*	Heriot-Watt University Edinburgh, Scotland	Same	A deeper, more powerful version of ANGUS. Under construction
CONSUB 1	2,000/ 610	British Aircraft Corp. Ltd. Bristol, England	Same	Operational
CONSUB 2	2,000/ 610	British Aircraft Corp. Ltd. Bristol, England	Same	Under construction. Completion date: mid-1977
CORD	1,500/ 457	Harbor Branch Foundation Ft. Pierce, Fla.	Same	Operational. Ultimate depth of 2,000 ft (610m)
CURV II	2,500/ 762	Naval Undersea Center San Diego, Ca.	Same	Operational
CURV II	2,500/ 762	Naval Undersea Center San Diego, Ca.	Naval Torpedo Station Keyport, Wa.	Operational
CURV III	10,000/ 3,048	Naval Undersea Center San Diego, Ca.	Same	Operational
CUTLET	1,000/ 305	Admiralty Underwater Weapons Establishment, Portland, England	Same	Operational. Two more units under construction
ERIC	1,640/ 500	French Navy Toulon, France	Same	Operational
EYE ROBOT	328/ 100	Mitsui Ocean Development & Engineering Co., Ltd. Tokyo, Japan	Same	Operational
MANTA 1.5	4,921/ 1,500	Institute of Oceanology Moscow, USSR	Same	Under construction
RCMV	NA	Oceaneering International Houston, Tx.	Same	Under development
RCV-150	6,000/ 1,829	Hydro Products San Diego, Ca.	See Note 2	Under construction
RCV-225	6,600/ 2,012	Hydro Products San Diego, Ca.	See Note 1	Operational
RECON II	1,500/ 457	Perry Ocean Group Riviera Beach, Fla.	Same	Operational
RUWS	20,000/ 6,096	Naval Undersea Center Honolulu, Hawaii	Same	Under construction. Completion date estimated by end of 1976

TABLE 4.2 UNMANNED, SELF-PROPELLED, TETHERED VEHICLES
(Continued)

VEHICLE	DEPTH (Feet/ Meters	BUILDER	OPERATOR	STATUS
SCARAB I & II	6,000/ 1,829	AMETEK Straza El Cajon, Ca.	NA	Under construction. Completion date: Jan. and Mar. 1977
SEA SURVEYOR	660/ 220	Rebikoff Underwater Prod. Ft. Lauderdale, Fla.	Same	Operational
SNOOPY	1,500/ 457	Naval Undersea Center San Diego, Ca.	Same	Operational
SNOOPY	1,500/ 457	Naval Undersea Center San Diego, Ca.	Naval Facilities Command Washington, D.C.	Operational
SNURRE	1,969/	Royal Norwegian Council for Scientific Research Oslo, Norway	Continental Shelf Institute Trondheim, Norway	
SUB 2	NA	Aldermaston/Institute of Geological Sciences Berkshire, England	NA	NA
TELENAUTE	3,280/ 1,000	Institut Francais du Petrole Paris, France	Same	Operational
TROV	1,200/ 366	McElhanney Offshore Survey & Engineering, Ltd. Vancouver, B.C.	Canada Ctr. for Inland Waters Burlington, Ontario	Operational
TROV OI	1,200/ 366	McElhanney Offshore Survey & Engineering, Ltd. Vancouver, B.C.	Underground Location Services, Ltd., Glasgow, Scotland	Operational

* Information not available.

1. Seven vehicles total. Seaway Diving, Bergen, Norway (2 vehicles); Martech International, Houston, Tx. (2 vehicles); SESAM, Paris, France (1 vehicle); Taylor Diving & Salvage, Belle Chasse, La. (1 vehicle); Esso Australia, Ltd., Sale Australia (1 vehicle)
2. Two vehicles total. Martech International, Houston, Tx. and Scandive, Stavanger, Norway

The basic tethered, self-propelled vehicle system consists of the vehicle itself (and sometimes an underwater clump or launcher); a cable and a shipboard control/display console. Supporting equipment includes a launch/retrieval device, a cable winch, sheltered areas for the vehicle operators and shipboard components and, if shipboard power is not available or suitable, a power supply unit. A unit such as Rebikoff's SEA SURVEYOR can be operated with much less equipment and facilities than listed above. On the other hand, the SCARAB vehicles and RUWS require more. It is obvious, after reviewing Section 3, that there is no "average" manned submersible. Likewise, there is no "average" unmanned submersible. For this reason an individual description of each system is presented. The following discussion deals with various aspects of these vehicles which bear on their applicability to manned submersible search and retrieval.

Operating Depth: Vehicles owned by the non-military sector range in depth capability from 660 ft (200m) to 6,600 ft (2,012m); the average is 4,283 ft (1,306m). Military-owned vehicles range from 1,000 ft (457m) to 20,000 ft (6,096m), with an average depth of 4,428 ft (1,350m). Until the RUWS is operational, every operating submersible except ALVIN and TRIESTE II can be reached by at least one device listed in Table 4.2.

Mobilization Time: In the previous section mobilization time was defined as that time required to load a system's components aboard a truck. This definition is the one used by the operators of TELEPROBE. The operators of ANGUS define it as the time it takes to install their system aboard a ship of opportunity. The definition of mobilization time, therefore, is not standard, and it is subject to a wide variety of factors. The operators of NAVFAC SNOOPY require

eight hours to load their system aboard a truck, but they caution that the system is not fully mobilized until a trained operator is located and brought aboard to accompany the system. If the SNOOPY system was in the midst of an overhaul, and in "kit" form, more than eight hours may be required for its mobilization. The larger and deeper CURV system state 72 hours as mobilization time; this can be reduced to 24 hours in an emergency.

A very practical measurement of CURV III's mobilization time from the point of being requested to the point of being launched for rescue was made during the PISCES III incident. From summons to launch, approximately 66 hours were required; this includes air transit from san Diego to Cork, Ireland and from Cork to the emergency site 250 nautical miles (463 km) distant.

In the final analysis, it is probably safe to assume that at least a minimum of eight hours would be required to mobilize the shallow-diving systems (this includes possible packaging and reassembly of the system and time spent in locating the operational crew) and at least 24 hours would be required for mobilization of the deeper, more complex systems.

Launch/Retrieval: The underwater component(s) or "vehicle" of these systems range from 150 lbs (68kg) to as much as 5,000 lbs (2,268kg). In one instance, the manufacturer states that one man can "easily" launch the vehicle without the aid of a mechanical advantage. It would be safe to assume that most men would find even the lightest vehicle a challenge to pick up and lower into the water, regardless of the amount of freeboard. In all other instances, a handling frame of some sort is required of the support craft or carried or recommended as part of the system.

The sea state limitations on launch/retrieval are a direct reflection of the nature and sophistication of the shipboard handling equipment. The unmanned system, in spite of the fact that the retrieval line is always attached, is as vulnerable as the manned system when contact with the sides of the support platform is a possibility. Because most of these systems are designed for deployment from a ship of opportunity, it is not possible to place a sea state limit on the system until the handling gear is specified.

Some indication of sea state limits can be gained from the following operator statements: CONSUB 1 can be launched/retrieved through sea state 4; DEEP DRONE is designed to be handled up through sea state 5 if "normal" handling equipment is available which is employed to handle manned submersibles. These vehicles are not the heaviest vehicles operating (3,000 lbs (1,360kg) and 1,200 lbs (544kg) respectively), but they do fall around the average vehicle weight of 2,118 (961kg). While operational data under heavy sea conditions is sparse, it would appear that up to and including sea state 5 from any ship of opportunity is a limit for normal operations. In an emergency situation this limit may be exceeded, but not without the possibility of severely damaging the components by slamming the vehicle into the support craft. A further complicating factor accompanying high sea states is the ability of the support craft to maintain station. It may well be that launch/retrieval in sea state 6 or 7 is possible, but the ship itself cannot keep station to control the vehicle in its search pattern or rescue role.

Speed: The speed of unmanned vehicles is quite similar to those found in manned vehicles, and ranges, at the surface, from one to five knots (1.8 to 9.3 km/hr). From a search/retrieval consideration, the lowest range of speed is adequate if it can be obtained at the depth of operation and under prevailing currents.

An unmanned vehicle's surface (forward) speed (i.e., with little or no cable drag) decreases considerably with depth. On the individual vehicle description sheets a value is given for the maximum current speed under which a vehicle can maintain forward motion at its operational depth. This same value can be interpreted as its maximum forward speed at its operational depth. This same value can be interpreted as its maximum forward speed at operational depth under no currents. The decrease in speed with increase in currents ranges from 20 percent to 84 percent of the surface speed, and averages about 42 percent. The SCARAB vehicles, for example, can make 3 knots (5.6 km/hr) on the surface, but only 0.5 knots (0.9 km/hr) at 6,000 ft (1,829m), an 84 percent decrease. The RCV-225 makes 1.7 knots (3.1 km/hr) on the surface and 1.0 knot (1.8 km/hr) at 6,600 feet (2,012m), a 42 percent decrease. This difference in reduction is brought about by the different modes of deploying the vehicles. The SCARAB vehicles are designed to cruise along the bottom,towing the entire length of cable while the support craft maintains station directly over the vehicle. The RCV-225 is deployed from a launching cage and works around the launcher on 394 feet (120m) of tether cable; hence, the amount of cable drag is substantially reduced. For this reason many of the unmanned vehicles now employ a launcher or clump which holds the major portion of the umbilical cable taut and reduces cable drag.

The reduction in speed with depth does not, in most open ocean areas, detract from the unmanned vehicle's capability to perform as a submersible search/retrieval asset, because 0.5 to 1 knot currents are not generally encountered except in areas such as the Gulf Stream or Kuroshio Current. Areas such as the North Sea are a different situation. In the Frigg field, for example, current speeds (tidally induced) of 0.6 knots (1.1 km/hr) and greater are common, while

farther south in the Deborah, Dottie and Lemon Bank fields up to 3 knots (5.6 km/hr) of current are present. In such areas the effectiveness of the unmanned (and manned as well) vehicles is reduced considerably, if not completely.

Maneuverability: All but a few vehicles are capable of two translation motions and one rotational motion; these are thrust (forward/reverse) and heave (up/down); and yaw (left/right) heading changes, respectively. These motions are provided by the arrangement of two horizontal or forward thrusters and one vertical thruster. By adding a forth lateral or side thruster, a third translational motion is obtained: sway or sidle; if this thruster is mounted forward it is used to augment yawing, rather than providing a sideward translational motion. Pitch motion is not common and can only be found on the CONSUB vehicles where two forward/aft-mounted vertical thrusters can impart pitch to the vehicle by operating in opposing directions. Be designing its television camera mounting such that it can be trained $\pm$ 90 degrees from the horizontal plane, the manufacturers of RCV-225 have provided a substitute for pitching the entire vehicle. No unmanned vehicle is known to have a roll motion.

The umbilical cable offers an obvious potential for fouling, but this is a constraint under which the operator must work and he has no choice but to be selective in his job applications. Less obvious is the possibility for imparting too many twists in the cable. Hydro Products has included a counter/display unit for measuring the number of twists and their direction. From a search/rescue point of view, the maneuverability of unmanned, self-propelled vehicles appears more than adequate to the task.

Instrumentation: The instruments discussed here are those applicable to search and retrieval of a manned submersible; these tasks imply location of the submersible

evaluation of the predicament (e.g., source and nature of the entanglement), and the capability for taking corrective action, such as cutting a cable or attaching a line for surface retrieval. The instruments listed in Table 4.3 are those considered applicable to these tasks and are a standard piece of onboard equipment. There are numerous equipment options on virtually all unmanned vehicles, however, these options are not listed because they reflect what the vehicle could be, not what it is.

All operating unmanned vehicles have a closed circuit television system. Combining this real-time viewing capability with the excellent maneuverability provides an ideal means of inspecting and evaluating a submersible's situation. Locating the submersible may be a more difficult proposition. The Hydro Product's low light level SIT television camera's viewing range is, in clear water with no ambient light, 23 to 33 feet (7 to 10m). While it is possible that an unmanned device will eventually find a target by systematically searching within its 33 feet viewing range, it is not practical to count on this approach considering the limited life support available to the submersible occupants. There are three potential means of reducing the search time: 1) by visually following a marker buoy attached to the vehicle, or 2) by homing in on the submersible's pinger, or 3) by searching for the submersible with CTFM or scanning sonar. The first of these methods, following a marker buoy, is not quite as simple as first appears because of the precise control needed to maintain visual (TV) contact with the marker line. Buoyed lines rarely remain perfectly vertical and they are subject to lateral excursions which may transport the line out of the field of view. While this location method is feasible, it is not practical. The best method of location is homing on an active acoustic target attached to the submersible.

This procedure can quickly bring the unmanned vehicle within television viewing range. Scanning and CTFM sonar is also quite effective, but, if the submersible is entangled in a ship or other large structure, differentiating the submersible's acoustic reflection from the wreck may be time-consuming, if not impossible. The best method, therefore, is homing on an active target. Table 4.3 shows that only six out of 25 vehicles have this capability. Consequently, while all unmanned vehicles are potentially excellent evaluation tools, only 24 percent have the capability of applying this asset in the most effective manner to a stricken manned submersible.

Manipulators: The capability to provide corrective action resides in the vehicle's ability to manipulate or cut a line or cable, or to attach a retrieving line from the surface. In either case a grasping ability is a major asset. Approximately 50 percent of the unmanned vehicles have a manipulator capability. Four vehicles (RECON II, SCARAB I & II and RCV-150) provide cable cutting terminations as standard equipment. RECON II has the capability of cutting through a 5/8 in. (1.6cm) diameter wire rope.

Cable cutting capabilities are not presently available for the SCARAB vehicles, but they would seem well-suited for this task as they are intended for use as cable repair/recovery vehicles.

The most applicable and immediate role unmanned vehicles can play is to attach a lift line to the submersible; this task also requires a manipulator or grasper to carry and attach the line to the submersible. In view of the unmanned vehicles' maneuverability, a manipulator not anymore dexterous than RECON II's (linear extension, wrist rotate, claw open/close) could satisfy the manipulative function.

TABLE 4.3 WORK INSTRUMENTS

	--VIEWING/PHOTOGRAPHY--					-----SONAR----			
	TV	STILL	STEREO	CINE	MANIPU-LATOR	SEARCH	HOMING	CURRENT METER	THERMISTOR
ANGUS	X			X			X		
CONSUB 1	X		X						
CONSUB 2	X		X						
CORD	X				X	X		X	X
CURV II (2 ea)	X	X			X	X	X		
CURV III	X	X			X	X	X		
DEEP DRONE	X	X				X	X		
ERIC	X	X			X				
EYE ROBOT	X								
MANTA 1.5	X				X				
RCV-150	X								
RCV-225 (5 ea)	X								
RECON II	X				X			X	
RUWS	X					X	X		
SCARAB I & II	X	X			X(2)				
SEA SURVEYOR	X								
SNOOPY (2 ea)	X			X					
SNURRE	X		X	X	X		X		
TELENAUTE	X			X	X				
TROV (2 ea)	X				X(2)				

However, the depth of operation, diameter of the retrieving cable and prevailing current strength may place severe limits on the unmanned vehicle's effectiveness.

Only two vehicles carry current measuring devices (CORD and RECON II) and only one, CORD, includes a water temperature sensor. These data are of value in assessing the type and potential effectiveness of the retrieval systems which could be employed.

Crew: For routine operations the support crews range from one to seven in numbers with three to four being average. The CURV-type vehicles require up to ten personnel in an emergency. Commercial operators of unmanned vehicles do not specifically define a routine operation; it is assumed that eight to ten hours is routine. In an emergency situation a 24 hour capability is required; if the CURV vehicles can be used as a guide, then somewhere between four to six personnel would be necessary to operate and support the vehicles over a 24 hour period.

Navigation: Submerged navigation of unmanned vehicles is similar to those described in Section 5.5 for manned vehicles. Descriptions of each vehicle's approach to navigation are presented on the individual data sheets.

ANGUS

Operating Depth: 984 ft (300m)
Dimensions (LxWxH): 74 in. x 41 in. x 51 in. (188cm x 104cm x 130cm)
Weight (dry): 840 lbs (386kg)
Speed: (Max. Surface) 2 knots (3.7 km/hr)
(Max. Operating Current) 0.75 knot (1.3 km/hr)
Structure: Cylindrical steel body (MK 30 torpedo shell) with a forward plastic hemi-head mounted on an aluminum sled. The cylinder is pressure-compensated with compressed air controlled by a standard scuba demand regulator.
Buoyancy: Positive and/or negative buoyancy is obtained by pumping sea water into or out of four tanks (two forward, two aft) underneath the vehicle body. Pitch/trim is obtained by pumping sea water forward or aft in the four tanks.
Power Requirements: All electrical power is supplied by a 3-phase 440 V 6 KVA 50 Hz diesel generator.
Propulsion: Two fixed, reversible, lateral thrusters mounted port and starboard and one vertical thruster. Each thruster (propeller) is driven by a 1.5 hp, 3-phase, oil-filled, induction motor, and each is capable of independent operation.
Instrumentation: One TV camera, one Super 8 cine camera, two 500 watt quartz iodide lights, hydrophone (25 kHz), wide band hydrophone (0-200 kHz), magnetic compass, echo sounder, pressure transducers, roll/pitch transducer.
Navigation: A two-transponder relative positioning system has been developed and tested. Repeatability of less than 2 meters (6.6 ft) on a 1 km (0.5 nm) base-line was obtained, no attempt has been made to assess the system's accuracy.
Shipboard Components: Diesel generator, Earth Leakage Protection Unit (circuit breakers), control console, (CCTV monitor, compass repeater, roll & pitch indicators, buoyancy and trim meters, depth readout, voltage and current monitors), cable reels (400 meters/1,312 ft total), tool box, navigation control console and underwater transponders are essential.
Support Ship Requirements: Any craft in excess of 12 meters (39 ft) length and equipped with a derrick capable of lifting the vehicle.
Operation/Maintenance Crew: Two: one engineer, one technician
Total Shipping Volume: 783 ft^3 ($22m^3$)
Total Shipping Weight: 3 tons (2.7t)

Status: ANGUS is a research/development vehicle only and has no operational status. A new ANGUS 002, which will have increased depth capability and greater propulsive power is currently being constructed.
Builder: Dept. of Electrical & Electronic Engineering
Heriot-Watt University
31-35 Grassmarket, Edinburgh EH1 2HT
Scotland
Operator/Point-of-Contact: Robin T. Holmes
(address same as builder)
Telephone: 031-225-8432 ext. 104

CONSUB 1

Operating Depth: 2,000 ft (610m)
Dimensions (LxWxH): 107 in. x 72 in. x 57 in. (271cm x 182cm x 145cm)
Weight (dry): 3,000 lbs (1,360kg)
Speed: (Max surface) 2.5 kts (4.6 km/hr)
(Max Operating Current) 2 kts (3.7 km/hr) at 2,000 ft. (610m)
Structure: Tubular aluminum alloy HE 130
Buoyancy: Two cylindrical, pressure-resistant, fiberglass cylinders provide a positive buoyancy of 40 lbs (18kg) when vehicle is submerged
Power Requirements: 240 V 50 Hz single phase 3 KVA, 415 V 50 Hz 3-phase 50 KVA (to the control cabin transformer). If the latter is not available a diesel generator can be used. Surface transformer converts supply voltage to 415 V/1000 V 3-phase for transmission to vehicle.
Propulsion: Two lateral and two vertical fixed, reversible thrusters. All are electro-hydraulically powered, 5 hp each, and capable of independent operation.
Instrumentation: Compass, inclinometer, depth gauge, two TV cameras (1 color; 1 black and white), stereo camera system, rock drill capable of taking a 0.5 in. (1.3cm) diameter 5 in. (13cm) long core. Stereo and TV cameras are mounted on a pan and tilt unit which trains ±150 degrees in azimuth and tilts +30 degrees to -90 degrees from the horizontal.
Navigation: No underwater positioning system in operational configuration, can be configured to utilize the SCANTIE System.
Shipboard Components: Control console (2 TV monitors; vehicle/instrument controls), Transformer, System Distribution Box (connects transformer, ship junction box and consoles) Ship Junction Box (terminates umbilical cable of support craft) and Faking Frame (for storage and deployment of umbilical).
Support Craft Requirements: Launch/retrieval system capable of supporting vehicle dry weight. Freeboard not to exceed 12 ft (3.7m). Deck space: 10 ft x 10 ft (3m x 3m) clear space with tiedowns for vehicle; area of 20 ft x 20 ft (6m x 6m) required for umbilical cable faking frame. Cabin space: 1) must be large enough to contain a 7 ft (2.1m) long bench for control console at which two operators sit, and must also provide a view of operational deck area; 2) bulkhead area 3 ft x 4 ft (0.9m x 1.2m) for distribution box; 3) deck space in cabin of 2 ft x 2 ft (0.6m x 0.6m) for transformer and 4) an access port of 5 in. (12.7cm) diameter is required for electrical service cables.
Operating/Maintenance Crew: Three to four
Total System Shipping Volume: NA
Total System Shipping Weight: 6,100 lbs (2,767kg) (approximate)

Status: Operational. Has conducted a variety of commercial and scientific in the U.K. offshore area.
Builder: British Aircraft Corp. Ltd.
Bristol, England
Operator / Point-of-Contact: Electronic & Space Systems Group
British Aircraft Corp. Ltd.
GPO Box 77
Filton House, Bristol BS99 FAR
England
Telephone: Bristol (0272) 693831 ext. 811
Telex: 44188

CONSUB 2

Operating Depth: 2,000 ft (610m)
Dimensions (LxWxH): 145 in. x 84 in. x 66 in. (368cm x 213cm x 168cm)
Weight (dry): 4,400 lbs (1,996kg)
Speed: (Max. Surface) 2.5 kts (4.6 km/hr)
(Max. Operating Current) 2 kts (3.7 km/hr) at 2,000 ft
Structure: Tubular aluminum alloy HE 130
Buoyancy: Syntactic foam blocks provide positive buoyancy.
Power Requirements: 380/415/440 V 50/60 Hz 3-phase 50 KVA (to control cabin transformer)
Propulsion: Four, fixed, reversible, electric thrusters with Kort nozzles. Two are for forward propulsion, one for lateral movement and one for vertical motion. A TV camera will be mounted on a rotating platform stabilized in azimuth relative to rest of vehicle, the controls will be arranged such that the vehicle will travel in the direction in which the operator points the camera.
Instrumentation: Two TV cameras (color; black & white), stereo camera system mounted on a pan and tilt mechanism similar to CONSUB 1. Depth gauge, magnetic compass. Special payload arrangements will allow a wide variety of work tools and sampling devices. In the event of power loss to the vehicle, a self-powered transponder is activated.
Navigation: A system called SCANTIE (Submersible Craft Acoustic Navigation and Tract Indication Equipment) is integral to the vehicle. In its basic form it measures horizontal range, compass bearing, depth and heading of the vehicle relative to the support craft. Slant range accuracy is $\pm$0.75m (2.5 ft), horizontal range accuracy is $\pm$0.3% out to 1.5 km (0.8nm) and bearing is accurate to $\pm$1 degree within 360 degrees. The SCANTIE system can be expanded to operate in a range-range mode relative to a bottom-mounted transponder array. Basic display is a color CRT on which graphic and alpha-numeric data is presented.
Shipboard Components: Same as CONSUB 1 except that: 1) a mechanical cable handling unit will take place of the faking frame and, 2) the SCANTIE display and processing console may be included.
Support Craft Requirements: Clear deck space (with tie-downs): 15 ft x 18.4 ft (4.6m x 5.6m) for vehicle; 20 ft x 6.5 ft (6m x 2m) for cable handling device. Derrick or crane capable of lifting vehicle with an outreach of 6.5 ft (2m) from the support craft. Two cabins, each 19.7 ft x 8 ft x 8.5 ft (6m x 2.4m x 2.6m). Station Keeping requirements dependent upon depth of vehicle and strength of current.
Operating/Maintenance Crew: Four
Total Shipping Volume: NA
Total Shipping Weight: NA

Status: Under construction, scheduled for operations by spring 1977
Builder: Same as CONSUB 1
Operator/Point-of-Contact: Same as CONSUB 1

CORD

Operating Depth: 1,500 ft (457m); 2,000 ft (610m) goal
Dimensions (LxWxH): 68 in. x 41 in. x 55 in. (173cm x 104cm x 140cm)
Weight (dry): 720 lbs (327kg)
Speed: (Max. Surface) 5 kts (9 km/hr)
(Max. Operating Current) 2 kts (3.7 km/hr) at 1,500 ft
Structure: A U-shaped 10 in. (25cm) aluminum tube provides flotation and serves as storage and protection for the bulk of the electronics. The base of the vehicle consists of two rectangular oil-filled pods which serve as the hydraulic reservoir and as mounting locations for electronic and hydraulic components.
Buoyancy: U-shaped, 10 in. (25cm) diameter, pressure-resistant, aluminum tube provides positive buoyancy when surfaced. Buoyancy submerged can be controlled by ± 15 lbs (6.8kg) through displacement of oil into and out of a soft bladder.
Power Requirements: 5 KW 480 V 3-phase 60 Hz provided by an alternator in SEA GUARDIAN (its support craft) which is hydraulically powered by a 115 hp Ford diesel engine. A 0.35 in. (0.9cm) diameter, 1,850 ft (564m) long, armored, coaxial cable serves as the umbilical between support craft and vehicle.
Propulsion: Four hydraulically-powered, fixed, reversible propellers driven by a 3 hp hydraulic motor. Two thrusters supply forward-aft motion (thrust), one provides vertical motion (heave) and one provides lateral motion (yaw). All have continuously variable speed control.
Instrumentation: Television and light on pan & tilt mechanism (360 degrees azimuth; 110 degrees downward from the horizontal), current speed sensor, temperature sensor, echo sounder. Magnetic compass, pressure/depth transducer, scanning sonar (360 degree scan, 200 kHz search; 500 kHz local) with CRT display. Manipulator: hydraulically-powered, two degrees-of-freedom, scissors-type claw.
Navigation: CORD is equipped with a 25 kHz pinger which can be powered from the surface or is self-powered and pings at repetition rate of once/second. Its support craft deploys three hydrophones, one mounted on the starboard forward quarter, one amidships portside, and one on the starboard side astern. The three hydrophones receive the outgoing ping and onboard electronics process the signal by triangulation to provide a CRT display showing the pinger's position relative to the three hydrophones. Accuracy of CORD's position relative to its support craft had not been determined at the time of this survey.
Shipboard Components: CORD is deployed from an aluminum surface utility craft, SEA GUARDIAN, which has the following dimensional characteristics:

Length:	23 ft (7m)	Speed (loaded):	8 kts (14.8 km/hr)
Beam:	9 ft (2.7m)	Range:	60 nm (111 km)
Draft:	2 ft 1 in. (0.6m)	Weight (loaded):	4.5 tons (4.1t)

All controls and displays for the operation and monitoring of CORD are aboard SEA GUARDIAN. Power is provided by a 115 hp Ford diesel engine which drives three hydraulic pumps which power the main hydrostatic transmission propulsion system, a 5 KW alternator and bow and stern thrusters as well as a line hauler and storage reel. A dynamic positioning system, within an enclosed cabin, maintains SEA GUARDIAN in position over CORD. At present, CORD can only be fully deployed and operated from SEA GUARDIAN.
Support Craft Requirements: At present CORD can only be fully deployed and operated from SEA GUARDIAN.
Operating/Maintenance Crew: Three
Total Shipping Volume: 49.3 yd^3 (37.5m^3) approximate
Total Shipping Weight: 4.9 tons (4.4t) approximate

Status: Undergoing operational sea trials; has dived to 1,000 feet (305m).
Builder: Harbor Branch Foundation, Inc.
Rt. #1, Box 196
Ft. Pierce, Fl. 33450
Operator/Point-of-Contact: Same as above
Telephone: (305) 465-6400

CURV II

Operating Depth: 2,500 ft (762m)
Dimensions (LxWxH): 180 in. x 72 in. x 72 in. (457cm x 183cm x 183cm)
Weight (dry): 3,450 lbs (1,565kg)
Speed: (Max. Surface) 4 kts (7.4 km/hr)
(Max. Operating Current) NA
Structure: Rectangular-shaped open aluminum framework encloses and supports all components. Syntactic foam blocks are affixed atop the framework.
Buoyancy: Syntactic foam blocks provide slight positive buoyancy submerged.
Power Requirements: 440 VAC, 120 VAC 3-phase 50 KW. A portable, 60 KW diesel generator supplies all power to the system.
Propulsion: Three, 10 hp, pressure-compensated, electric motors provide power to three propellers. Two provide forward-reverse motion and one provides vertical motion. All are capable of independent operation.
Instrumentation: Television (2 ea.), 35mm still camera, lights, altimeter, depthometer, magnetic compass, active and passive CTFM sonar (AMETEK Straza Mfg.). Manipulator, hydraulically-powered, three degrees-of-freedom, circular-type (torpedo grasping) claw.
Navigation: By compass bearing and visual sighting. Can interrogate bottom-mounted transponder to obtain relative position. Can locate pinger and "home" in on target.
Shipboard Components: Control/display console (in a portable van), power supply (generator) and conversion equipment, and surface handling equipment.
Support Ship Requirements: Station-keeping capability and cable handling area away from screws. Deck space for seven items approximately 75 to 120 ft^2 (7 to 11.2m^2) each.
Operational/Maintenance Crew: Seven normally, ten in an emergency mission
Total Shipping Weight: 26 tons (23.6t) (not including handling crane)
Total Shipping Volume: 4,500 ft^3 (127.4m^3). For operations to 1,500 ft (457m) the total system (not including handling crane) can be loaded aboard on C-141 aircraft on known ship of opportunity. For emergency operations on unknown ship of opportunity, two C-141s are required.

Status: Operational. Two identical CURV IIs are in operation, one at NUC, San Diego and one at the Naval Torpedo Station, Keyport, Wa.
Builder: Naval Undersea Center
San Diego, Ca.
Operator/Point-of-Contact: Mr. H.R. Talkington
Naval Undersea Center (Code 65)
San Diego, Ca. 92132
Telephone (714) 225-7811
Autovon: 933-7147

Commanding Officer
Naval Torpedo Station
Keyport, Wa. 98345
Telephone (206) 326-2511/2512/2514
Autovon: 744-2511/2512/2514

CURV III

Operating Depth: 10,000 ft (3,048m)
Dimensions (LxWxH): 150 in. x 78 in. x 78 in. (457cm x 183cm x 183cm)
Weight (dry): 4,000 lbs (1,814kg)
Speed: (Max. Surface) 4 kts (7.4 km/hr)
(Max. Operating Current) NA
Structure: Same as CURV II
Buoyancy: Same as CURV II
Power Requirements: Same as CURV II
Propulsion: Same as CURV II
Instrumentation: Same as CURV II
Navigation: By compass heading and visual sighting. The support craft, YFNX-30, is equipped with a Boat-Mounted Acoustic Locating Device (BALD) which monitors CURV III's relative bearing during a dive.
Shipboard Components: Same as CURV II
Support Ship Requirements: Same as CURV II. For local area operations, the YFNX-30 serves as its support craft. YFNX-30 has the following characteristics: Length 110 ft (33.5m), beam 34 ft (10.4m), draft 5 ft (1.5m), freeboard 6.5 ft (2m), speed 5.5 kts (10.2 km/hr).
Operational/Maintenance Crew: Same as CURV II
Total Shipping Weight: Same as CURV II
Total Shipping Volume: Same as CURV II

Status: Operational
Builder: Naval Undersea Center
San Diego, Ca.
Operator/Point-of-Contact: Mr. H.R. Talkington
Naval Undersea Center (Code 65)
San Diego, Ca. 92132
Telephone (714) 225-7811
Autovon: 933-7811

DEEP DRONE

Operating Depth: 2,000 ft (610m)
Dimensions (LxWxH): 84 in. x 54 in. x 48 in. (213cm x 137cm x 122cm)
Weight (dry): 1,400 lbs (635kg)
Speed: (Max. Surface) 3.5 kts (6.5 km/hr)
(Max. Operating Current) 2 kts (3.7 km/hr) at 2,000 ft (estimated)
Structure: Two, pressure-resistant flotation tanks atop of - and enclosed within - an open, tubular aluminum framework.
Buoyancy: Positive buoyancy of 45 lbs (20kg) is provided by the flotation tanks when submerged. Negative buoyancy is dynamically-provided by the thrusters.
Power Requirements: 115 VAC 1-phase 2 KVA, 440 VAC 3-phase 10 KVA. Umbilical consists of 3,000 ft (914m) long, 0.75 in. (1.9cm) diameter coaxial cable with strength member. A diesel motor generator provides all power required to operate the vehicle system.
Propulsion: Three thrusters, two are for forward-aft propulsion (thrust and yaw) and one is for vertical propulsion (heave). Each motor is fixed, reversible, shrouded by a Kort nozzle and rated at three shaft horsepower at 1,725 rpm.
Instrumentation: Two TV cameras, one is fixed and one is mounted on a pan and tilt mechanism, 70mm still camera with strobe light, CTFM sonar with transponder interrogation and pinger location capabilities, altimeter, depth meter.
Navigation: The CTFM sonar is designed to interrogate a bottom-mounted transponder and, using it as a benchmark, can conduct search patterns out to 3,000 ft (914m). The sonar can also interrogate more than one transponder to establish its position. A locator system aboard the surface craft can obtain the vehicle's relative range and bearing.
Shipboard Components: Control console, control cable and basket, support line and A-frame, vehicle locator, diesel motor generator, support spare parts.
Support Ship Requirements: Enclosed area for control console and operators, lift boom of one ton (0.9t) capacity, deck capstan for retrieval of umbilical, station-keeping ability if conducting underway operations.
Operation/Maintenance Crew: Four man (minimal - more depending on nature and length of task).
Total Shipping Weight: 5 tons (4.5t)
Total Shipping Volume: 4,000 ft^3 (113m^3). Will ultimately be packaged for shipment in two standard LD-9 air cargo containers.

Status: Operational, on standby for emergency calls.
Builder: AMETEK, Straza Division
El Cajon, Ca. 92022
Operator/Point-of-Contact: Thomas B. Salmon
Naval Sea System Command
Supervisor of Salvage
Washington, D.C. 20362
Telephone: (202) 697-7403
Autovon: 227-7403

ERIC

Operating Depth: 1,640 ft (500m)
Dimensions (LxWxH): 158 in. x 71 in. x 79 in. (400cm x 180cm x 200cm)
Weight (dry): 4,049 lbs (2,000kg)
Speed: (Max. Surface) 2 kts (3.7 km/hr)
(Max. Operating Current) 1.5 kts (2.8 km/hr)
Structure: Rectangular shape composed of open aluminum framework which encloses and supports all components.
Buoyancy: The vehicle is 110 lbs (50kg) possitively buoyant
Power Requirements: 60 Hz, 3-phase, 440 VAC, 90 KW
Propulsion: Three thrusters, two provide thrust and yaw and one provides vertical motion. All thrusters are reversible; have continuously variable speed control and are capable of independent operation.
Instrumentation: TV on pan and tilt mechanism, six lights, still camera, depth gauge, CTFM sonar, inclinometer (pitch; roll) downward-looking echo sounder, magnetic compass, magnetometer. One manipulator with five degrees-of-freedom, parallel jaws-type claw.
Navigation: Compass heading, visual sighting and by interrogation of transponders with the CTFM sonar.
Shipboard Components: Control/Display console (in portable van), cable and winch, launch/retrieval crane.
Support Ship Requirements: Deck space for van and component storage.
Operation/Maintenance Crew: Five
Total Shipping Weight: 11 tons (10t)
Total Shipping Volume: 1,588 ft^3 ($45m^3$)

Status: Operational
Builder: Centre d'Etudes et de Recherches Techniques Sous-Marines
D.C.A.N. Toulon
France
Operator/Point-of-Contact: Mr. le Capitaine de Corvette
Commandant la Division des
S.M. d'Intervention et du Bathyscaphe
GISMER
83800 TOULON - NAVAL - FRANCE
Telephone: (94) 24 9100 - poste 21090

EYE ROBOT

Operating Depth: 328 ft (100m). Emergency dive to 492 ft (150m)
Dimensions (LxWxH): 100 in. x 74 in. x 49 in. (255cm x 189cm x 150cm)
Weight (dry): 1,984 lbs (900kg)
Speed: (Max. Surface) 2 kts (3.7 km/hr)
(Max. Operating Current) 2.5 kts (4.6 km/hr) at 328 ft (100m) depth
Structure: An acrylic plastic, tear drop-shaped shell enclosed and supports a pressure-resistant inner shell consisting of a transparent acrylic plastic hemisphere joined to a steel sphere. The inner shell contains a TV camera and its telemetry control unit and the thruster orientation units. Metallic skids support the vehicle on deck or when bottomed.
Buoyancy: The vehicle is 13 lbs (6kg) positively buoyant when submerged.
Power Requirements: 440 VAC, 60 Hz, 3-phase, 30 KVA
Propulsion: Two, oil-filled, reversible thrusters are mounted port/starboard amidships (1 on each side). Each thruster can be rotated ±90 degrees in the vertical plane and each is rated at 2 hp (1.5 KW)
Instrumentation: One color TV with mirrow pan and tilt unit. Eight 500 watt halogen lights, compass, inclinometer (pitch), depth gauge, speedometer, transponder. A bilateral, force feedback manipulator is planned for installation by March 1977.
Navigation: Compass heading and visual sighting. A transponder on the vehicle is interrogated to provide slant-range and bearing from the support ship.
Shipboard Components: Control/display console; power panel, cable winch.
Support Craft Requirements: One (1) ton (0.9t) capacity boom with 6 ft (2m) outreach for launch/retrieval of vehicle. Deck space of 20 ft x 20 ft (6m x 6m)
Operation/Maintenance Crew: Three to four
Total Shipping Volume: Approximately 989 ft^3 ($28m^3$)
Total Shipping Weight: Approximately 5 tons (4.5t)

Status: Operational. Not available from September 1976 through March 1977 due to installation of the manipulation system.
Builder: Mitsui Ocean Development & Engineering Co., Ltd.
Tokyo, Japan
Operator/Point-of-Contact: New Products Center
Mitsui Ocean Development & Engineering Co., Ltd.
2-5 Kasumigaseki 3-Chome
Chiyoda-Ku Tokyo, Japan
Telephone: Tokyo (03) 581-2301
Telex: J 24978

MANTA 1.5

Operating Depth: 4,921 ft (1,500m)
Dimensions (LxWxH): 78 in. x 62 in. x 40 in. (198cm x 158cm x 107cm)
Weight (dry): 2,200 lbs (998kg)
Speed: (Max. Surface) NA
(Max. Operating Current) NA
Structure: NA
Buoyancy: NA
Power Requirements: 380 VAC 3-phase 50 Hz
Propulsion: Four thrusters, two provide fore-aft thrust and yaw, two provide vertical motion (heave). All are fixed, reversible and 1.5 hp each.
Instrumentation: Television, lights (2 at 500 watts), manipulator with 7 degrees-of-freedom, capable of 2.2 tons (2t) lift capacity and has various types of claws.
Navigation: TV provides for visual navigation.
Shipboard Components: NA
Shipboard Requirements: NA
Operator/Maintenance Crew: Three
Total Shipping Weight: NA
Total Shipping Volume: NA

Status: Under construction (Jan. 1976)
Builder: Academy of Sciences USSR
Moscow
Operator/Point-of-Contact: Mr. A. Monin, Director
Institute of Oceanology USSR
1 Letnay St., Moscow 109387
Telephone: 233-55-76
Cable: G-387 OCEANOLOGIYA

RCV-150

Operating Depth: 6,000 ft (1,829m)
Dimensions (LxWxH): 36 in. x 38 in. x 29 in. (91cm x 96cm x 71cm). Operates from a launching unit on a 200 ft (61m) long tether cable.
Weight (dry): 450 lbs (204kg)
Speed: (Max. Surface) 2 kts (3.7 km/hr)
(Max. Operating Current) 2 kts (3.7 km/hr) at 6,000 ft.
Structure: Tubular aluminum framework encloses and supports all components. Atop and port/starboard on the framework are two cylindrical, fixed buoyancy units composed of a high strength composite epoxy and two spherical, variable buoyancy tanks mounted forward/aft on the vehicle's centerline. Mesh screen guards enclose the port and starboard sides of the aluminum framework.
Buoyancy: The high strength composite epoxy provides 15 lbs (7kg) of positive buoyancy when the vehicle is submerged. Variable ballast tanks can provide ± buoyancy when submerged.
Power Requirements: 220 or 440 VAC, 50/60 Hz, 3-phase
Propulsion: Four ducted propellers: two provide forward/reverse thrust and yaw rotation, one provides vertical thrust and one provides transverse or side motion. All thrusters are reversible. An automatic servo control system automatically corrects for external forces acting on the vehicle and automatically controls depth.
Instrumentation: TV camera (low light level) capable of being tilted ±90 degrees from the horizontal, 500 watt quartz iodide light, depth sensor, heading sensor, emergency pinger and flasher. A wide variety of optional equipment is available.
Navigation: By compass heading and visual sighting.
Shipboard Components: Control/display console, hand controller, winch, A-frame, hydraulic power supply, vehicle protective launcher.
Support Ship Requirements: Enclosed area for control/display console, deck space for vehicle and handling equipment, station-keeping capability and electric power supply (a diesel generator power source is optional).
Operation/Maintenance Crew: Three for an 8 to 10 hour period
Total Shipping Weight: 1,100 lbs (495kg), not including deployment unit, winch and cable, or handling equipment.
Total Shipping Volume: 252 ft^3 (7.1m^3), not including deployment unit, winch and cable, or handling equipment.

Status: Under construction; scheduled for delivery in April 1977 to Martech International, Houston, Tx., a 2nd vehicle is under construction for Scandive, Stavanger, Norway.
Builder: Hydro Products
San Diego, Ca.
Operator/Point-of-Contact: See "Status."

RCV-225

Operating Depth: 6,600 ft (2,012m)
Dimensions (HxWxD): 20 in. x 26 in. x 20 in. (51cm x 66cm x 51cm)
Launcher (HxWxD): 3.7 ft x 3.2 ft x 3.2 ft (1.1m x 1.0m x 1.0m)
Weight (dry): 180 lbs (82kg) Launcher (dry)L 175 lbs (80kg)
Speed: (Max. Surface) 1.7 kts (3.1 km/hr)
(Max. Operating Current) 1 kt (1.8 km/hr) at 6,600 ft
Structure: A syntactic foam hull shaped into a prolate spheroid encloses the motors and the camera/electronics pressure housing.
Buoyancy: Vehicle is positively buoyant by 4 lbs (2kg)
Power Requirements: 220 VAC 3-phase 50 to 60 Hz or 440 VAC 3-phase 50 to 60 Hz (5 KW maximum).
Propulsion: Four oil-filled electric motors, two provide thrust and yaw and two provide heave, a forth motion (sway) is provided by the vertical thruster configuration. A desired depth and heading can be automatically maintained.
Instrumentation: TV camera (low light level) which is capable of being tilted +90 degrees in the vertical, two 45 watt tungsten halogen lights, compass and depth sensor.
Navigation: By compass heading and visual sighting
Shipboard Components: Control/display console, power supply, hand controller, deployment unit (winch/skid/A-frame).
Support Ship Requirements: Enclosed area for control console.
Operation/Maintenance Crew: Two to three, depending upon length of task.
Total Shipping Weight: 5,555 lbs (2,519kg)
Total Shipping Volume: 285 ft^3 (8.1m^3)

Status: Seven of these vehicles have been built and sold to the following commercial organizations: Seaway Diving, Bergen, Norway (2 vehicles); Martech International, Houston, Tx. (2 vehicles); SESAM, Paris, France (1 vehicle); Taylor Diving & Salvage, Belle Chasse, La. (1 vehicle); Esso Australia, Ltd. Sale, Australia (1 vehicle)
Builder: Hydro Products
San Diego, Ca.
Operator/Point-of-Contact: See Status

RECON II

Operating Depth: 1,500 ft (457m)
Dimensions (LxWxH): 42 in. x 38 in. x 32 in. (107cm x 96cm x 81cm) Launcher: 36 in. x 30 in. x 36 in. (91cm x 76cm x 91cm).
Weight (dry): 620 lbs (281kg) Launcher: 1,500 lbs (680kg)
Speed: (Max. Surface) 3 kts (5.6 km/hr)
(Max. Operating Current) 2 kts (3.7 km/hr)
Structure: Syntactic foam atop an open tubular framework.
Buoyancy: Operates at neutral buoyancy. Descends/ascends by operation of thrusters.
Power Requirements: 220 VAC or 440 VAC 3-phase, 60 Hz
Propulsion: Four fixed, reversible, hydraulically-driven, propellers, each provides 1 hp. Two provide thrust and yaw, one provides vertical motion and one provides side motion. All are capable of independent operation and have continuously variable speed control.
Instrumentation: TV camera, two 250 watt incandescent lights, magnetic compass, depth monitor, current meter. One hydraulically-powered manipulator with 14 inches (36cm) linear extension, 90 degree wrist rotation and cable cutting/scissors-type jaws.
Navigation: By compass heading and visual sighting, or surface tracking.
Shipboard Components: Control console, cable umbilical, transformer package. Tracking system optional. TV monitoring and recording equipment.
Support Ship Requirements: One and one-half ton (1.5t) winch, 2,000 ft (610m) of 8,000 lbs (3,629kg) wire rope, power supply.
Operational/Maintenance Crew: Three
Total Shipping Weight: 2,100 lbs (952kg) not including control console, umbilical bundle, or items listed under support ship requirements.
Total Shipping Volume: 65.8 ft^3 (1.9m^3) not including umbilical bundle.

Status: Operational
Builder: Perry Ocean Group
Perry Building, P.O. Box 10297
Riviera Beach, Fl. 33404
Telephone: (305) 842-5261
Telex: 51-3439
Operator/Point-of-Contact: Same as above

RUWS

Operating Depth: 20,000 ft (6,096m)
Dimensions (LxWxH): Vehicle - 132 in. x 57 in. x 54 in. (335cm x 145cm x 137cm); PCT - 115 in. x 76 in. x 115 in. (292cm x 193cm x 292cm)
Weight (dry): Vehicle - 5,800 lbs (2,631kg); PCT - 5,000 lbs ± 300 lbs (2,268kg ± 136kg)
Speed: (Max. Surface) 1 kt (1.8 km/hr)
(Max. Operating Current) 1 kt (1.8 km/hr)
Structure: Vehicle: Rectangular shape composed of open angular aluminum framework supporting and enclosing all components, syntactic foam blocks are affixed to the top of the framework. PCT (Primary Cable Termination): Rectangular shape composed of open, angular aluminum framework which encloses and supports a winch for the vehicle's buoyant, 850 ft (259m) long tether and four thrusters for station-keeping and maneuvering.
Buoyancy: Syntactic foam provides the vehicle with 10 to 20 lbs (4.5 to 9kg) positive submerged buoyancy. The PCT is negatively buoyant by 3,000 ± 300 lbs (1,361 ± 136kg).
Power Requirements: All power, 60 KW, is supplied by diesel-electric generators.
Propulsion: A 15 hp hydraulic pump provides power to five thrusters: two for forward/reverse motion, two for lateral motion and one for vertical motion. All are reversible and continuously supply variable speed control.
Instrumentation: TV (head coupled), still camera (70mm), two manipulators - one with force feedback, search/avoidance sonar, two directional hydrophones, downward-looking echo sounder (altitude), magnetic compass.
Navigation: A real-time CRT display of the support ship, vehicle and PCT positions can be obtained relative to three bottom-mounted transponders which are interrogated individually by each component. Relative position accuracies of ± 5 feet (1.5m) are obtainable at maximum operating depth. A hard copy of the CRT-displayed data may be obtained at the operator's discretion.
Shipboard Components: Control/navigation van; maintenance van; near-surface navigation transducer with handling system; power generation equipment and a motion-compensated, deck handling system.
Support Ship Requirements: A minimum deck space of 541 ft^2 ($50m^2$) is required to accommodate all surface and underwater components.
Operational/Maintenance Crew: Not yet established, but a maximum of 15 have accompanied RUWS during current field tests.
Total Shipping Weight: 70 tons (63.5t)
Total Shipping Volume: Entire system (5 modules) can be accommodated by a Lockheed C-141A aircraft.

Status: Undergoing sea trials and tests, estimated operational by December 1976.
Builder: Naval Undersea Center
Honolulu, Hawaii
Operator/Point-of-Contact: Same as above

SCARAB I & II

Operating Depth: 6,000 ft (1,829m)
Dimensions (LxWxH): 132 in. x 72 in. x 60 in. (335cm x 183cm x 152cm)
Weight (dry): 5,000 lbs (2,268kg)
Speed: (Max. Surface) 3 kts (5.6 km/hr)
(Max. Operating Current) 0.5 kt (0.9 km/hr) at 6,000 ft
Structure: Open tubular framework cage enclosing and supporting vehicle components.
Buoyancy: Cylindrical flotation tanks provide 50 lbs (23kg) of positive buoyancy when submerged.
Power Requirements: 480 VAC 3-phase 100 KW. Portable gas/diesel electric generator supplies all power requirements. A 10,000 ft (3,048m) long umbilical cable 1.4 in. (3.2cm) diameter powers and controls the vehicle.
Propulsion: Six, 5 hp each, electrical motors and one, 5 hp, hydraulic motor provide propulsive power.
Instrumentation: Two low light level TV cameras (one with zoom) on pan and tilt units, one 35mm still camera, lights, bottom contour following sensors, altimeters, depth sensors, magnetometer (for cable location). Two hydraulically-powered manipulators, 5 degrees-of-freedom, equipped with various devices for cable cutting and gripping. Dredge or jet pump to uncover and bury cables.
Navigation: 360 degree scanning CTFM sonar capable of interrogating bottom-mounted transponder or locating pingers for relative bottom positioning. Computer driven graphics display tracking unit on support craft for obtaining vehicle's relative range and bearing.
Shipboard Components: Power distribution unit, control/display console, navigation plotter, operator's chairs (three each), spare parts, diesel generators, cable, cable floats, vehicle locator unit and motion compensated launcher with cable storage reel.
Support Ship Requirements: Deck space for shipboard components and vehicle.
Operation/Maintenance Crew: Operator, assistant operator and observer
Total Shipping Weight: 80,000 lbs (36,288kg)
Total Shipping Volume: Nine standard air freight containers hold all components. Volume of each container (LD-3) is 158 ft^3 (4.5m^3).

Status: Both vehicles are under construction. SCARAB I will be completed in November 1976 and II in February 1977. Both units will be maintained on 24 hour standby basis.
Builder: AMETEK/Straza
El Cajon, California
Operator/Point-of-Contact: Both vehicles are being built for a consortium of telephone companies. Headed by AT&T. Point-of-Contact is:
Joe Poythress, Manager, Overseas Facilities Maintenance
SCARAB Consortium Construction Manager
AT&T Long Lines
No. 5 World Trade Center
New York, N.Y. 10048
Telephone: (212) 393-5366

SEA SURVEYOR

Operating Depth: 660 ft (200m)
Dimensions (LxWxH): 132 in. x 48 in. x 28 in. (335cm x 122cm x 171cm)
Weight (dry): 385 lbs (175kg)
Speed: (Max. Surface) 5 kts (9.3 km/hr)
(Max. Operating Current) 3 kts (5.6 km/hr) at 660 ft
Structure: Torpedo-shaped metallic body with forward dive planes and stern-mounted propeller.
Buoyancy: All depth control is by dynamic propulsion
Power Requirements: 230 V 60 Hz 4 KW
Propulsion: Stern-mounted, reversible propeller
Instrumentation: TV camera, light, depth sensor, gyrocompass
Navigation: By compass bearing and visual sighting and artificial horizon
Shipboard Components: Display/Control panel
Support Ship Requirements: Station-keeping ability required
Operational/Maintenance Crew: One
Total Shipping Weight: NA
Total Shipping Volume: NA

Status: Operational
Builder: Rebikoff Underwater Products, Inc.
Ft. Lauderdale, Fl.
Operator/Point-of-Contact: Rebikoff Institute of Marine Technology, Inc.
3060 S.W. 4th Ave.
Ft. Lauderdale, Fl. 33315
Telephone: (305) 522-5572
Telex: 514534

SNOOPY (ELECTRIC)

Operating Depth: 1,500 ft (457m)
Dimensions (LxWxH): 40 in. x 26 in. x 18 in. (101cm x 66cm x 46cm)
Weight (dry): 150 lbs (68kg)
Speed: (Max. Surface) 1 kt (1.8 km/hr)
(Max. Operating Current) 1 kt (approximate)
Structure: Syntactic foam mounted atop an open, tubular, aluminum framework. Two, cylindrical, pressure-resistant, aluminum housings with plexiglass endcaps for housing electronics.
Buoyancy: Syntactic foam provides slight positive buoyancy when submerged.
Power Requirements: 115 VAC 60 Hz 1.2 KW umbilical cable consists of two small (RG-58) coaxial cables (one for power and control signals and one for video signal) and a strength member, married together.
Propulsion: Three fixed and reversible oil-filled thrusters each powered by pressure-compensated DC motors. Two are stern-mounted to provide forward-aft motion (thrust) and one is mounted amidships to provide vertical motion (heave). All motors have continuously variable speed control.
Instrumentation: TV camera and 8mm cine camera (one in each aluminum housing), quartz iodide light, magnetic compass, depth transducer.
Navigation: By compass, heading and visual (TV) sighting.
Shipboard Components: Control console (TV monitor, vehicle and instrument controls), cable storage bin.
Support Ship Requirements: Small boat davit, 5 ft x 8 ft (1.5m x 2.4m) deck area, station keeping ability desireable.
Operating/Maintenance Crew: Two
Total Shipping Weight: 1,200 lbs (544kg)
Total Shipping Volume: Approximately 100 ft^3 (2.8m^3)

Status: Operational
Builder: U.S. Naval Undersea Center
San Diego, Ca.
Operator/ Same as above
Point-of-Contact: Mr. H. R. Talkington
Naval Undersea Center (Code 65)
San Diego, Ca. 92132
Telephone (714) 225-7147

SNOOPY (NAVFAC)

Operating Depth: 1,500 ft (457m)
Dimensions (LxWxH): 46 in. x 28 in. x 24 in. (117cm x 71cm x 61cm)
Weight (dry): 300 lbs (136kg)
Speed: (Max. Surface) 2 kts (3.7 km/hr)
(Max. Operating Current) 1.5 kts (2.8 km/hr) at 1,500 ft.
Structure: Similar to ELECTRIC SNOOPY
Buoyancy: Similar to ELECTRIC SNOOPY
Power Requirements: Similar to ELECTRIC SNOOPY. Umbilical consists of one cable (RG-58) and an auxiliary strength member.
Propulsion: Four, fixed and reversible thrusters. Two are stern-mounted to provide forward-aft motion (thrust), one is mounted amidships to provide lateral motion (sway) and one is mounted amidships atop the lateral thruster to provide vertical motion (heave). An automatic altitude/depth "hold" mode of operation is provided.
Instrumentation: TV camera, super 8mm cine camera, quartz iodide light, magnetic compass, depth transducer.
Navigation: By compass heading and visual sighting.
Shipboard Components: Control/display console, power converter box, power booster box, cable tank.
Support Ship Requirements: Station-keeping and handling crane
Operational/Maintenance Crew: Two
Total Shipping Weight: 1,370 lbs (621kg)
Total Shipping Volume: 111 ft^3 (3.1m^3) in five containers

Status: Operational
Builder: U.S. Naval Undersea Center
San Diego, Ca.
Operator/Point-of-Contact: Walter G. Hilsabeck
Chesapeake Div. Code FPO 1
Naval Facilities Command
Washington Navy Yard
Washington, D.C. 20374
Telephone (202) 433-3881

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SNURRE

Operating Depth: 3,280 ft (1,000m)
Dimensions (LxWxH): 79 in. x 71 in. x 59 in. (200cm x 180cm x 150cm)
Weight (dry): 2,645 lbs (1,200kg)
Speed: (Max. Surface) 1.5 knots (2.8 km/hr)
(Max. Operating Depth) NA
Structure: Rectangular shape, open aluminum tubular framework encloses and supports vehicle components. A syntactic foam block is affixed to the top of the framework.
Buoyancy: Vehicle has slightly positive buoyancy when submerged. Descent/ascent are dynamically controlled.
Power Requirements: 3-phase, 420 VAC, 40 KVA. Supplied by a diesel-electric surface generator.
Propulsion: Four thrusters total. Three provide forward and lateral motion and can be tilted from the horizontal plane upward to 90 degrees. One thruster is located in the center of the vehicle and provides vertical motion.
Instrumentation: TV (2 ea.) can be tilted 90 degrees upward and 20 degrees downward from the horizontal and are mounted to provide stereoscopic viewing; two 8mm cine cameras; two stereoscopic still cameras; two, 250 watt, quartz-iodide lights, depth gauge; altimeter (echo sounder); gyrocompass; two hydrophones receiving from 0-20 kHz; manipulator with cable-cutting capability.
Navigation: A three-transponder, bottom-mounted navigation system has been developed which will provide position accuracies of 2 to 5 meters (6 to 16 ft) relative to the transponders at a maximum range of 1,500 meters (4,921 ft).
Shipboard Components: Control/display console, diesel generator, cable winch, launch/retrieval facility.
Support Ship Requirements: Deck space for one 20 ft (6m) standard ISO container, 4 x 6 meter (13 x 20 ft) deck space for vehicle.
Operational/Maintenance Crew: Four to five for a 12 hour working day.
Total Shipping Volume: Two, 20 ft (6m) standard ISO containers.
Total Shipping Weight: Six tons metric (6.6 short tons)

Status: Operational since spring 1974, major overhaul in spring 1975, has been extensively employed in the North Sea and coastal Norwegian waters since 1975.
Operator/Point-of-Contact: Continental Shelf Institute
Box 1883
Hakon Magnussons gt, 1B
7001 TRONDHEIM
Norway

TELENAUTE 1000

Operating Depth: 3,280 ft (1,000m)
Dimensions (LxWxH): 130 in. x 67 in. x 60 in. (330cm x 170cm x 152cm)
Weight (dry): 2,420 lbs (1,097kg)
Speed: (Max. Surface) 3 kts (5.6 km/hr)
(Max. Operating Current) NA
Structure: NA
Buoyancy: NA
Power Requirements: 380 VAC 3-phase 50 Hz 50 KW. A surface generator supplies all electrical power.
Propulsion: Three propellers, each is driven by a 3.5 hp hydraulic motor. Two provide forward-reverse motion and one provides vertical motion. All can be independently controlled. An automatic altitude "hold" mode of operation is provided by regulating the vertical thruster with input from a downward-looking echo sounder.
Instrumentation: TV camera, 16mm cine camera, six 500 watt lights, magnetic compass, pressure/depth gauge, echo sounder. Manipulator, hydraulically powered, 110 lb (50kg) lift capacity, various claw terminations.
Navigation: By compass bearing and visual sighting.
Shipboard Components: Cabin containing control/display console and generator, cable storage drum.
Support Ship Requirements: NA
Operational/Maintenance Crew: NA
Total Shipping Weight: 5,940 lbs (2,694kg)
Total Shipping Volume: 795 ft^3 (22.5m^3)

Status: Reported as operational
Builder: Institut Francais du Petrole
1N4 Avenue Bois Preau
Paris
France
Operator/Point-of-Contact: Same as above

TROV

Operating Depth: 1,200 ft (366m)
Dimensions (LxWxH): 68 in. x 36 in. x 44 in. (173cm x 91cm x 112cm)
Weight (dry): 1,130 lbs (513kg)
Speed: (Max. Surface) Approximately 1.5 kt
(Max. Operating Current) 1 kt (1.8 km/hr) at 1,200 ft
Structure: Open, rectangular-shaped, aluminum framework encloses and supports all components.
Buoyancy: Floodable ballast tanks emptied by compressed air.
Power Requirements: Lead acid batteries (7 ea.) in a pressure-resistant container provide all electrical power. Normal dive duration is three hours (depending upon work load). Umbilical cable 1,500 ft (457m) for instrument/vehicle control and data telemetry.
Propulsion: Four, reversible propulsion units, each provides 18 lbs (8.2kg) of thrust and all are capable of independent operation. Two provide forward-reverse motion, one provides vertical motion and one lateral motion.
Instrumentation: Television camera, two 55 watt quartz halogen lights, magnetic compass, echo sounder, transponder interrogator. Manipulator, hydraulically-powered, scissors-type claw, 4 degrees-of-freedom, 100 lbs (45kg) static lift capacity.
Navigation: By compass bearing and visual sighting. Can interrogate two bottom-mounted transponders concurrently for relative positioning using a Mesotech system.
Shipboard Components: Control/display console, cable winch, power pack for control console, spare power pack (batteries) for vehicle.
Support Ship Requirements: Deck space: 100 ft^2 (9.3m^2) open; 100 ft^2 enclosed.
Operational/Maintenance Crew: Three
Total Shipping Weight: 2,900 lbs (1,315kg)
Total Shipping Volume: 103 ft^3 (2.9m^3)

Status: Operational
Builder: McElhanney Offshore Surveying & Engineering Ltd.
Vancouver, B.C.
Canada
Operator/Point-of-Contact: Mr. John Roe
Diving Officer
Canada Centre for Inland Waters
P.O. Box 5050
Burlington, Ontario
Canada

TROV-0I

Operating Depth: 1,200 ft (366m)
Dimensions (LxWxH): 84 in. x 50 in. x 50 in. (213cm x 127cm x 127cm)
Weight (dry): 1,600 lbs (726kg)
Speed: (Max. Surface) 5 kts (9.3 km/hr)
(Max. Operating Current) 1.5 kts (2.8 km/hr) at 1,200 ft
Structure: Open, rectangular-shaped, aluminum framework encloses and supports all components.
Buoyancy: Floodable ballast tanks, emptied by compressed air.
Power Requirements: Requirements not specified, all electrical power will be supplied by a 20 KVA surface generator.
Propulsion: Four, reversible propulsion units, all capable of independent operation. Two provide forward-reverse motion, one provides vertical motion and one lateral motion.
Instrumentation: Television camera (black & white or color), three 500 watt lights, magnetic compass, echo sounder, transponder interrogator. Two, hydraulically-powered manipulators, scissors-type claw, 5 degrees-of-freedom, static lift capacity of 200 lbs (91kg) each.
Navigation: By compass bearing and visual sighting. Has capability to navigate relative to bottom-mounted transponders.
Shipboard Components: Console, 30 KVA generator, winch
Support Ship Requirements: Deck space: 200 ft^2 (18.6m^2) open; 100 ft^2 (9.3m^2) enclosed.
Operational/Maintenance Crew: Three
Total Shipping Weight: 5,525 lbs (2,506kg)
Total Shipping Volume: 1½ A2 modules in a 747 aircraft

Status: Operational. Has completed more than 60 North Sea dives as of 12 July.
Builder: McElhanney Offshore Surveying & Engineering Ltd.
Vancouver, B.C.
Canada
Operator/Point-of-Contact: Mr. E.J. Pope
Offshore Resources Ltd.
7 Radnor Close
Henley-on-Thames
Oxfordshire, England

4.2 AMBIENT PRESSURE DIVING SYSTEMS

The ambient diver's role in submersible search is limited, simply because all deep ambient diving (i.e., arbitrarily taken as greater than 300 ft or 91m with 2 to 4 hours working time/diver) is conducted from a surface-tethered bell which is supported by a surface platform in a minimum two-point moor. Consequently, the diver's ranging ability is restricted to the length of his bell-attached umbilical. An exception to this is found in the lockout submersibles where the submersible's cruising range is the major limiting factor.

With respect to retrieval, however, the diver is unquestionably the most potentially effective capability available and, if suitably equipped and tooled, there are few situations wherein he cannot attach a retrieving line to any of the present submersible lift points, or clear away entrapping debris.

The number of commercial diving companies throughout the world probably numbers in the thousands, and the range in capabilities is wide. To list each diving company would verge on the encyclopedic; consequently, a sampling of the major companies is considered as representative of the present maximum capabilities of the field at large. This is presented in Table 4.4, and includes military and academic (non-profit) activities as well as commercial.

Depth: The deepest working dive to date was performed in 1975 by COMEX to a depth of 1,015 feet (309m). Table 4.4 lists the maximum depth reached (performed) during a working dive. The U.S. Navy has gone much deeper than 930 feet (283m), but 930 feet was given as the depth to which a diver would be sent to work. For purposes of testing or experimentation, the depth reached is far greater.

TABLE 4.4 REPRESENTATIVE AMBIENT DIVING CAPABILITIES

	DEPTH			CONSTRAINTS			
	Max. Capability (ft/m)	Max. Performed[1] (ft/m)	Mobilization Time	Temp. (Min.)	Currents (Max.) kts - km/hr	Sea State (Max.)	Support Platform[5]
Can-Dive Ltd. Vancouver, B.C.	600/183	600/183	48 hrs.	None	NA[4]	7	4-pt. moor
COMEX Marseilles, France	1,500/457	1,015/309	48 hrs.	None	NA	NA	2-pt. moor
Harbor Branch Foundation Ft. Pierce, Fl.	1,000/305	600/183	Continuous standby	40° F	2 - 3.7	5	Station-keeping[3]
IUC[2] City Island, N.Y.	1,200/366	765/233	24 hrs.	None	1.5 - 2.8	5	1 to 3-pt. moor
Oceaneering Int. Houston, Tx.	1,200/366	600/183	NA	None	NA	NA	2-pt. moor
Ocean Systems Inc. Houston, Tx.	1,500/457	740/226	24-48 hrs.	None	3 - 5.6	6	4-pt. moor
Santa Fe Eng. & Constr. Houma, La.	1,000/305	600/183	12 hrs.	None	3 - 5.6	5	4-pt. moor
Sub Sea Oil Services Milan, Italy	1,000/305	933/284	12-24 hrs.	None	3 - 5.6	NA	4-pt. moor
Taylor Diving & Salvage Belle Chasse, La.	1,200/366	540/165	24 hrs.	None	1.5 - 2.8	6	8-pt. moor
U.S. Navy	850/259	930/283[6]	Continuous standby	None	3 - 5.6	NA	4-pt. moor

[1] At-sea working dive

[2] International Underwater Contractors

[3] Lockout submersible, no tether

[4] All work to date has been conducted in virtually zero currents; limits unknown.

[5] Routine mooring requirements; all could probably reduce to 2-point moor in emergency.

[6] Excursion dive from 850 ft (259m).

Most commercial diving is not conducted at the greatest depths reached; 300 to 400 feet (91 to 122m) is the current average working depth. However, in an emergency situation, where human life is at stake, it is difficult to place an absolute maximum depth on the diver's capabilities.

Mobilization Time: Twenty four to 48 hours is considered as the time required to assemble the divers and place the diving hardware aboard a truck. In two instances (Table 4.4) the equipment is already aboard a ship and ready-to-go, hence, the designation "continuous standby." Obviously, the operational crew of either system is not standing at the ready at any given moment. Some time must be allowed for assembling the crew.

Water Temperature Limitations: With the advent of the heated diving suit, there is no minimum water temperature that would preclude diving operations. The Harbor Branch Foundation's limit of 40 degrees F (4.4 degrees C) is brought about by the lack of heating facilities in the lockout submersibles they use for diver support.

Current Limitations: Three knots (5.5 km/hr) is the generally accepted limit in which the ambient diver can be expected to work. Divers have reportedly worked in faster currents, but the work was conducted under an elaborate system of guidelines (i.e., cables) to stabilize the bell and provide handholds for the divers. It is assumed herein that in an emergency situation, there would not be sufficient time to establish such a complex of guide cables and, therefore, three knots is taken as a realistic maximum. Although currents were not measured, it is estimated that 0.4 to 2.5 knots (0.7 to 4.6 km/hr) of current were present at the site of the 1973 JOHNSON-SEA-LINK I tragedy. This current was of such strength that divers could not work without jeopardizing their own lives.

Sea State Limitations: Sea State is a limiting factor in regard to the surface support platform's ability to hold station or to moor prior to launching the diving bell. The Sea State limits presented in Table 4.4 are limits for routine working dives, and in many instances are post-dive estimates rather than observed values. Obviously, the type of support platform will govern the Sea State limitations. International Underwater Contractors has conducted diving operations in 40 ft (12m) seas (State 9), but this was from a semi-submerged rig.

Support Platforms: In virtually all ambient diving operations, the support ship is first put in to, at least, a 2-point moor. The exception is the Harbor Branch Foundation, where there is no tether to the surface. This mooring practice is noted herein because it is another time-consuming factor of the stricken vehicle's life support duration. No realistic average value can be given for the time it would take to moor, owing to the many factors which enter into the picture, e.g., weather, currents, depth, number of points, expertise of the crew. For comparative purposes, the USS TRINGA (ASR 16) required 4 hours to establish a 4-point moor over the JOHNSON-SEA-LINK in 360 feet (110m) of water.

5.0 OPERATIONAL PROCEDURES, INSTRUMENTS AND SUPPORT

5.1 Emergency Devices and Procedures

The following summations describe equipment carried aboard submersibles which may play a vital role in search and retrieval of a stricken vehicle. Much of this equipment is not considered "emergency" per se by the operators, e.g., underwater telephones, lights, scanning sonars, surface communications, lift points, etc., but their use by a submersible to either locate another vehicle or assist another vehicle in locating and retrieving itself prompts this categorization. For comparative purposes, Table 5.1 is included to provide easy reference to the field at large. It should be noted that the instruments and devices mentioned below are those submersibles are using, not what they could use. There are a wide variety of new or different commercially available products other than what is described, but the purpose of this Handbook is to show what is, not what could be.

5.1.1 Underwater Telephones

All submersibles carry a means of communicating with the surface. Three submersibles carry two underwater telephones, one for routine use and one for back-up. In every instance an acoustic (wireless) device is employed. The predominant frequency is 8 kHz, which is UQC compatible. In most of the vehicles built since 1970, a second frequency is included in the telephone which is less susceptible to interference; 27 kHz is favored as the second choice. Most vehicles provide an emergency source of in-hull power for the underwater telephone in case the main power fails. Several options are offered in various of the commercial underwater telephones. The AMETEK Model ATM-504A

TABLE 5.1 SUBMERSIBLE COMPONENTS RELATED TO SAFETY, SEARCH AND RETRIEVAL

	VEHICLE COLOR	UQC FREQ.[1]	PINGERS NO.	PINGERS FREQ.	AVOIDANCE SONAR TYPE	AVOIDANCE SONAR FREQ.	TRANS-PONDER FREQ.	DIRECT. ANTEN.	EMERG. POWER	SURF. COMM.	RDF BEACON	SURF. LIGHT	RADAR REFLEC.	ROCKETS/ FLARES NO.	ROCKETS/ FLARES COLOR	SMOKE SIGNALS NO.	SMOKE SIGNALS COLOR	EMERG. MARKER BUOYS	LIFE JACKETS	LIFE RAFTS	AUTO. DEBAL-LASTING	EMERG. BREATHING OPEN	EMERG. BREATHING CLOSED	EGRESS	LIFT POINT SHAPE	MANIPULATORS NO.	MANIPULATORS DEG. FREE.	MANIPULATORS JETTI-SONABLE	MANIPULATORS CLAW TYPE	FIRE EXT.
ALVIN	White	8	1	37	CTFM	82-72	0[2]	0	X[3]	VHF,CB	X	X	X	24	Red	0		0	3	0	0	0	X	0	Circle	1	6	Yes	Various	1
AQUARIUS I	White Orange	9, 27	1	9, 27	Scan	160	0	0	X	VHF	X	X	0	6	Red	0		0	2	0	0	0	X	0	Circle	1	6	Yes	Scissors	1
ARGUS	Yellow	17	0	-	0	-	0	0	X	CB,VHF	0	0	0	0		0		0	3	0	0	0	X	0	Circle	0	-	-	-	1
AUGUSTE PICCARD	Orange Gray	8, 10 27	1	37	CTFM Scan	87-72 160	0	0	X	VHF	X	X	X	0		0		X	7	2	0	X	0	X	Circle	0	-	-	-	6
BURKHOLDER I	Yellow	8.5	0	-	Echo Sounder	50	0	0	0	CB	0	X	0	4	Red	0		X	2	0	X	0	X	0	Circle	1	6	No	Parallel jaws	1
CYANA	Yellow	8	1	37	CTFM	55-40	16-17	0	0	VHF	X	X	X	10	Red	0		0	3	3	0	X	0	0	Circle	1	5	Yes	Various	1
DEEP QUEST	White, Orange	8	2	27	CTFM	87-72	0	0	X	VHF	X	X	0	4	Red	0		0	4	0	0	0	X	0	Inverted "V"	2	6	Yes	Parallel jaws	2
DEEPSTAR-2000	White, Yellow	8	1 1	27 12	Scan	380	23-27	X	X	VHF	X	X	X	6	Red	6	Yellow	0	3	3	-	0	X	-	Circle	1	3	Yes	Orange peel	1
DEEPSTAR-4000	Yellow	NA	NA	-	NA	-	NA	NA	NA	VHF	0	X	X	NA		NA		X	3	0	0	X	0	0	NA	1	5	Yes	NA	1
DIAPHUS	White, Orange	8, 27	1	27	0	-	0	0	X	CB	X	0	0	0		0		0	2	0	0	X	0	0	Shackle	1	3	No	Scissors	1
DOMB	Red	NA	1	NA	Scan	NA	NA	X	X	NA	NA	NA	NA	NA		NA		NA	NA	0	0	NA	NA	0	Circle	2	NA	Yes	NA	2
DSRV I & II	Olive drab	8	1	12.5-17	CTFM	87-72	7	X	X	UHF	X	X	0	0		0		0	28	0	0	0	X	X	Shackle	1	6	Yes	Parallel jaws	3
GRIFFON	Yellow	8	1	14.5	CTFM	NA	25,8-9	0	X	UHF	0	X	0	0		0		X	2	0	0	0	X	0	Circle	1	6	Yes	Parallel jaws	2
NAUTO	Red, White	8	0	-	Scan	200	10-10	0	X	CB	0	X	0	0		0		0	3	0	0	X	0	0	Circle	1	5	Yes	Parallel jaws	1
JOHNSON-SEA-LINK I & II	Metallic, plastic	8	1 1	9, 45 37	CTFM	87-72	39-178	0	X	VHF(20)	0	X	0	6	Red	0		X	4	0	0	X	0	X	Housing	1	3	No	Various	2
LEO	White, Orange	9, 27	1	27	Scan	160	0	X	X	VHF	X	X	0	0		0		0	3	0	0	0	X	0	NA	1	6	Yes	Scissors	1
MERMAID II	White, Orange	8	2 2	45 37	Scan	160	0	0	X	CB	0	X	-	-		-		X	2	-	X	X	X	X	Inverted "U"	1	5	No	Scissors	1
MERMAID III & IV	Orange, Gray	NA	NA	-	NA	-	NA	NA	X	HF	0	X	0	0		0		X	NA	0	X	X	0	X	Elliptical	0	-	-	-	1
MOANA I	Gray, Orange, White	8	0	-	Scan	150	25-50	0	X	VHF	X	X	X	0		0		X	3	0	0	0	X	0	Hook	1	6	Yes	Parallel jaws	1
MOANA III, IV & V	Gray, White	8	0	-	Scan	150	0	0	X	VHF	X	X	X	2	NA	0		X	3	0	0	0	X	0	Circle	1	6	Yes	Parallel jaws	1
NEKTON A, B, C	Yellow	8	1	37	Scan	90-119	0	X	X	VHF	0	0	0	0		0		0	0	0	0	X	0	X	Shackle, Circle	1	NA	No	Scissors	0
NEMO	Plastic hull, Orange supports	8	1	NA	0	-	0	0	X	HF	0	X	0	0		0		X	0	0	0	0	X	0	Circle	0	-	-	-	1
PCB-B	Yellow	27	1	27	Scan	160	0	X	X	CB	0	X	0	0		1	Black	0	2	0	0	X	0	0	Hook	2	4 5	Yes Yes	Scissors Parallel jaws	1
PC-9	Orange, White	8 27	1 1	27 10	Scan	39	0	X	X	VHF	0	X	0	0		0		X	3	0	0	X	0	0	Hook	1	4	No	Parallel jaws	2
PC-1201	Yellow	27	1	27	Scan	160	0	X	X	CB	0	X	0	0		1	Black	0	2	0	0	X	0	0	Hook	2	4 5	Yes Yes	Scissors Parallel jaws	1
PC-1202	Yellow	27	1	27	Scan	160	0	0	X	CB	0	X	0	0		1	Black	0	5	0	0	X	0	X	Hook	2	4 5	Yes Yes	Scissors Parallel jaws	2

TABLE 5.1 (Continued)

	VEHICLE COLOR	UQC FREQ.[1]	PINGERS NO.	PINGERS FREQ.	AVOIDANCE SONAR TYPE	AVOIDANCE SONAR FREQ.	TRANS-PONDER FREQ.	DIRECT. ANTEN.	EMERG. POWER	SURF. COMM.	RDF BEACON	SURF. LIGHT	RADAR REFLEC.	ROCKETS/ FLARES NO.	ROCKETS/ FLARES COLOR	SMOKE SIGNALS NO.	SMOKE SIGNALS COLOR	EMERG. MARKER BUOYS	LIFE JACKETS	LIFE RAFTS	AUTO. DERAL-LASTING	EMERG. BREATHING OPEN	EMERG. BREATHING CLOSED	EGRESS	LIFT POINT SHAPE	MANIPULATORS NO.	MANIPULATORS DEG. FREE.	MANIPULATORS JETTI-SONABLE	MANIPULATORS CLAW TYPE	FIRE EXT.
PC-1203	Gray, White Orange	27	0	-	Scan	160	0	0	NA	VHF	0	NA	NA	0		0		NA	2	0	0	0	X	0	NA	2	5 6	No No	Parallel jaws	1
PC-14C-2	Yellow	27	1	45	0	-	0	0	0	VHF	0	0	0	0		0		0	2	0	0	X	0	X	Shackle	0	-	-	-	1
PC-16	NA	8, 27	0	-	Scan	160	0	0	NA	CB	0	X	0	0		NA		0	3	0	0	X	0	X	Circle	2	4 3	No No	Parallel jaws Scissors	X
PISCES II	Red	10, 27	1	10, 27	Scan	155	10-11	0	X	VHF	0	0	0	0		0		X	2	0	0	0	X	0	Rams Horn	2	2 6	Yes Yes	Parallel jaws Circular	2
PISCES III	White	10, 27	1	10, 27	Scan	155	10-11	X	X	VHF	0	0	0	0		0		X	2	0	0	0	X	0	Rams Horn	2	2 6	Yes Yes	Parallel jaws Circular	2
PISCES IV	Orange, White	8	1	27	Scan	165	23, 24 26, 27	0	X	CB	X	X	0	0		0		0	3	0	0	0	X	X	Hook	2	2 6	Yes Yes	Parallel jaws Circular	1
PISCES V	White	27, 10	2	27, 10	Scan	160	0	X	0	VHF	0	X	0	0		0		X	3	0	0	0	X	0	Shackle	2	2 6	Yes Yes	Parallel jaws Circular	1
PISCES VI	Red, White Green	8, 18	0	-	Scan	160	0	0	0	CB,VHF	X	X	0	0		0		X	3	0	0	0	X	0	Shackle	2	2 6	Yes Yes	Parallel jaws Circular	1
PISCES VII & XI	Red, White Green	8, 18	0	-	Scan	160	0	0	0	CB,VHF	X	0	0	0		0		X	3	0	0	0	X	0	Shackle	2	2 6	Yes Yes	Parallel jaws Circular	1
PISCES VIII & X	White	10, 27	1	10, 27	Scan	155	10-11	X	X	VHF	0	0	0	0		0		X	2	0	0	0	X	0	Rams Horn	2	2 6	Yes Yes	Parallel jaws Circular	2
PRV-2	White	8	0	-	0	-	0	0	X	CB	0	0	0	X	NA	0		0	3	0	0	X	0	X	Circle	1	NA	No	NA	3
PS-2	Yellow	27	1	NA	Scan	160	0	0	0	VHF	0	X	0	20	White, Red	0		X	2	0	0	X	0	X	Circle	1	3	No	Parallel jaws	1
SDL-1	Orange, White	8	1 1	27 8	Scan	160	0	0	X	VHF	0	X	0	0		0		0	6	0	0	X	0	X	Shackle	2	2 6	Yes Yes	Parallel jaws Circular	2
SEA CLIFF	White, Orange	8	0	-	CTFM	87-72	X	X	X	UHF	0	X	X	0		0		0	3	0	0	0	X	0	Loop	2	6	Yes	Various	1
SEA EXPLORER	Yellow	27	0	-	0	-	0	0	0	0	0	X	0	0		0		X	2	0	0	X	0	X	Circle	0	-	-	-	0
SEA OTTER	Yellow	27 42	1	27	Echo Sounder	NA	0	X	0	CB	0	0	0	1	Red, White	0		X	2	0	0	X	0	0	Circle	1	6	No	Dorrance	1
SEA RANGER	White, Blue	27	0	-	0	-	0	0	0	CB	0	0	0	0		0		0	2	0	0	X	0	X	Circle	2	2 4	Yes Yes	Pincer Pincer	1
SHELF DIVER	Yellow	27	1	37	Scan	160	0	0	X	UHF	0	X	0	1	White	0		X	5	0	0	0	X	0	Hook	1	4	No	Parallel jaws	1
SHINKAI	Yellow, Red	8	0	-	Scan	200	50-50	X	0	HF,VHF	0	X	0	0		0		0	8	0	X	X	0	X	Circle	1	6	Yes	Various	2
SKADOC 1000	Yellow	27	1	27	Scan	NA	0	0	0	VHF	0	X	0	0		0		X	2	0	0	X	X	X	Hook	0	-	-	-	1
SNOOPER	White	8	0	-	0	-	0	0	0	CB	0	0	0	0		0		X	2	0	0	X	0	X	Circle	1	3	No	Scissors	0
TAURUS	NA	NA	0	-	Scan	160	0	X	X	VHF	0	0	0	0		0		0	NA	0	0	0	X	0	NA	2	NA	NA	NA	NA
TRIESTE II	White	8	1	32, 37	CTFM	87-72	7	0	X	VHF	X	X	X	0		0		0	3	0	X	0	X	0	None	1	4	Yes	Parallel jaws	1
TURTLE	White, Orange	8	0	-	CTFM	87-72	X	X	X	UHF	0	X	X	0		0		0	3	0	0	0	X	0	Loop	2	6	Yes	Various	1
URF	Orange, White	8	1	37	CTFM	87-72	0	X	0	VHF	X	X	0	0		0		0	0	0	0	0	0	X	Circle	1	3	Yes	NA	4
VOL-L1	White	10, 27	1	10, 27	Scan	160	10-11	X	X	VHF	0	X	0	0		0		X	5	0	0	X	0	X	Circle	1	5	No	Parallel jaws	2

NOTES: 1 = All frequencies are kHz
2 = Not onboard
3 = Onboard

provides a TIPE option which includes pinging, interrogating, transponding or echo-sounding capabilities. All vehicles have one transducer mounted topside; a small number also have a bottom-mounted transducer which can serve as back-up surface communications when the vehicle is surfaced or assist in locating the vehicle when it surfaces in fog or at night.

Only one operating submersible does not have a regularly scheduled communications check with the surface support ship. The time period for communications check differs widely from vehicle-to-vehicle and ranges from once every five minutes to once every 35 minutes. All but four vehicles abort the dive if surface-to-submersible communications cannot be established within a certain time frame (60 minutes is the longest period). The vehicles that do not abort follow the procedure of allowing a certain time period for submergence; if an extension beyond this time is required the pilot is obliged to request permission. If communications cannot be established after the pre-established dive period, the vehicle must surface. Manufacturers of commercial underwater telephones, their frequencies and the number of submersibles using the particular model are shown below. Those submersibles which do not show a manufacturer, use models which they manufactured themselves.

Manufacturer	Frequency	Number in Use
AMETEK/Straza	8 kHz	7
Heele Engineering	27 kHz	9
Mesotech Systems	8 & 27 kHz	7
Hydro Products	8 kHz	3
CSF Thompson	8 kHz	1
Westinghouse Electric	8 kHz	1
Sub Comm	8 & 27 kHz	5
Spiro Technique	27 kHz	1

5.1.2 Scanning (Avoidance) Sonar

The primary role of scanning or avoidance sonars is to provide the pilot with visual and audio information regarding the presence of acoustically-reflective objects beyond his range of direct vision. Recent options have been added to provide additional capabilities, such as echo-sounding, transponder interrogation and navigation.

Three types of scanning sonars are found on todays' submersibles; these consist of: simple echo sounders where the transducer is mounted to point forward; transducers operating on one frequency which are mounted inside a pressure-compensated container and are trainable 360 degrees in the horizontal and to varying degrees in the vertical, and a transducer/hydrophone arrangement which is also 360 degrees trainable in the horizontal but transmits and receives on varying frequencies. Of these three types, the latter two are dominant, the first of these two being the WESMAR Scanning Sonar and the latter being the AMETEK Straza CTFM Sonar.

WESMAR (Western Marine Electronics) Scanning Sonars are found on 17 operational vehicles. This firm produces a variety of models (SS240ST, SS240S, SS140S) with varying capabilities. The most advanced model is the SS240ST whose operating specifications are listed below.

Frequency: 160 kHz (sonar); 25 kHz (transponder)

Maximum Range: Sonar mode: 3,200 ft (975m); transponder mode: 6,400 ft (1950m)

Operating Voltages: 12, 24, 32 VDC; 110 VAC, 60 Hz

Transmitter Power Output: 2,000 w peak-to-peak

Pulse Width: 0.7 to 0.9 ms. Transponder transmits 1.5 ms

Power Consumption: 35 w

Transducer Beam Width: 7 degrees

Transducer Tilt Range: +4 degrees upward to -90 degrees downward

Transducer Sweep Range: 360 degrees

Sector Scanning: 30 degrees to 360 degrees

Audio Power Output: 45 w peak-to-peak

Two display modes (in addition to an audio signal) are available: a CRT, B-SCAN Mode and a CRT, A-SCAN Mode. In the B-SCAN mode the targets are displayed (similar to search radar PPI presentation) in range and relative bearing to the submersible on a CRT. In the A-SCAN mode a horizontal line is displayed as a spike. The position of the spike on the line provides range to the target and the height and width of the spike indicates strength of target return.

In the transponder mode the transmit frequency is changed to 25 kHz. The transponder receives this pulse and responds on 160 kHz. The signal received is displayed as the usual echo to provide range, bearing and depth of the target. The transducer is also stabilized to compensate for ±25 degrees pitch and roll on the carrying vehicle. The ability to tilt the sonar scan +4 degrees above the horizontal and 90 degrees below the horizontal allows the SS240ST to serve as a homing device when surfaced and an echo sounder when submerged.

AMETEK/Straza CTFM sonars are found on ten operating vehicles. Several models are commercially available (500, 510, 520). The Straza Model 500 CTFM Scanning Sonar System is described below.

Frequency: Transmit: 87 to 72 kHz, Receiving: 87 to 72 kHz (sonar); 55 to 40 kHz (transponder); 36.5 to 37.5 kHz (marker).

Maximum Range: Sonar: 4,500 ft (1,372m); transponder (+50 dB target): 4,500 ft (1,372m); target (+25 dB target) 3,000 ft (914m)

Operating Voltages: (nominal) 27 VDC; 115 VAC, 60 Hz

Transducer Beam Width: 2 degrees

Sweep Range: 300 degrees (±150 degrees from 000 degrees relative) automatic

Sector Scanning: 60 degrees within ±180 degrees from 000 degrees.

The display mode for the CTFM 500 is in PPI format on a CRT and as an audio signal. It can also serve to interrogate transponders and to receive CW signals from marker beacons. The CTFM sonar techniques provide simultaneous portrayal of multiple objects which allows underwater navigation relative to a pre-set transponder array.

From Table 5.1 it is apparent that not all submersibles carry either form of scanning sonar. Significantly, all vehicles now engaged in offshore oil and gas tasks in the North Sea provide a scanning capability, particularly where precise submerged navigation is required. Equally significant, from a rescue point of view, the maximum range from which a transponder can be received is 6,400 ft (1,950m); the maximum range at which a reflective target can be obtained is 4,500 ft (1,372m); consequently, if a submersible is to acquire and home-in on a vehicle equipped with a compatible transponder, it must be within approximately one nautical mile (1.8km) slant range from the stricken vehicle to begin the closure.

5.1.3 Pingers

Well over half (65%) of the submersibles now operating or under construction include or plan to include an acoustic pinger as part of their operating equipment. Specific details of many pingers are not readily known by their users, and there are few generalizations which can be made regarding their operating characteristics. For these reasons, the following discussion is more qualitative than quantitative.

Frequency - Pinger frequencies range from 8 to 45 kHz. Approximately half of those in use are in the 27 to 37 kHz range. Many manufacturers offer dual frequencies on the same pinger, e.g., 9 and 45 kHz, 8 and 27 kHz or 10 and 27 kHz. Others, as noted under Section 3.2.1, provide a pinger option on their underwater telephone. The telephone/pinger option is economical, but if the pinger is a primary source for locating the vehicle in an emergency, the following conditions prevail: If the telephone transducer fails, the pinger will fail; if the pinger is being used, the telephone cannot be used, and the power required for the pinger draws off the same power needed for the vital communications link.

Power/Duration - Pingers are either self-powered or draw off the main batteries; a few have been modified to operate off both sources. Operating duration of a pinger is, obviously, directly related to the power supply. In instances where the pinger is self-powered and the repetition rate of the pulse prescribed, the duration can be specified and is found to range from three days to three months. In those cases where the pinger is powered off the main batteries, the operator has no clear idea of its operating duration and states it as "indefinite." A few operators have included an emergency power supply for the pinger, but they are a small minority.

Repetition Rate - Extremely variable from vehicle-to-vehicle, e.g., 1 ping/second, 2 pings/second, 5 pings/second. Some manufacturers refer to a "standard" repetition rate, but this standard is arbitrarily one of their own designation. The repetition rate on many pingers can be increased and decreased, which accounts for the wide variations in operating duration described above.

Activation - Pingers may be activated by the pilot or activated automatically by contact with salt water; no particular preference is seen in the field at large.

An increasing use of timed pingers for surface tracking by the support craft is noticeable. The AMF Acoustic Beacon (Mod. 395), for example, is used by several of the North Sea vehicles. The AMF Beacon can be activated at selectable periods from 10 to 100 seconds by a self-contained clock which is synchronized with a shipboard clock. The pulse received at the surface can be processed to supply both range and bearing to the submersible. The beacon transmits on 10 kHz, is self-powered and will operate for six months on a 20 second repetition rate.

5.1.4 Transponders

About 25 percent of all submersibles carry transponders. The frequencies shown in Table 5.1 are the interrogate-respond frequencies, respectively, and they vary widely according to the vehicle. The purposes for including a transponder are either for surface tracking or location of the vehicle in an emergency. The duration of transponder operation depends upon the frequency of interrogation. Many are powered by the main batteries and are classed as indefinite. Those which are self-powered can operate for as long as six months at a 30 second interrogate/respond rate.

5.1.5 Directional Antenna

A directional antenna (as used herein) consists of a housing containing a row of transducers or hydrophones which receive an acoustic pulse and inform the pilot of the horizontal bearing to the pulse source. This capability allows the submersible to home on an active and compatible acoustic source. A similar

capability is offered in the scanning and CTFM sonars, but the range of frequencies acceptable to the transducer is narrower.

Approximately 30 percent of all operating vehicles carry a directional antenna. The most common model is the Helle 6550 which receives between the range of 25 to 40 kHz. Other commercially available directional antenna in use are those produced by Hydro Products (27 kHz only) and another Helle model which receives on 10 or 27 kHz. The NEKTON series of vehicles use a Straza Co. Sea Probe which is manually trained and can receive between 20-54 kHz. The Japanese SHINKAI has two hydrophones mounted port/starboard; forward on the bow, and one mounted on the stern. These are used to receive a 50 kHz signal.

5.1.6 Emergency Power

An emergency power supply is carried in 65 percent of all submersibles. The power is derived from either nickel cadmium, silver zinc or lead acid batteries. No particular type of cell is most preferred. In most vehicles the emergency power is stored inside the pressure hull. The components which operate off the emergency batteries vary widely. In MERMAID II every electrical device, except the propulsion motors, can operate off the emergency power; in a large number of vehicles, only one component can operate with total power loss. In decreasing order of preference, the following devices are powered off the emergency batteries: underwater telephones, carbon dioxide scrubbers, radio transceivers, pingers, surface lights and navigation systems.

5.1.7 Surface Communications

All submersibles, but one, carry at least one radio transceiver for surface communications; seven vehicles carry two units; one is for routine use and one is for back-up. Approximately 51 percent carry VHF transceivers; 30 percent

use CB (HF); 1 percent use a combination of CB and VHF and 8 percent use UHF exclusively.

Power for surface communications is derived primarily from the main batteries. In a few instances, an emergency power source is supplied in addition to the main supply. Very few submersible operators know the operating duration of their transceiver; in only one instance was this available: JOHNSON-SEA-LINK I and II. The JOHNSON-SEA-LINK transceiver is self-powered and is of eight hours duration at 5 percent transmit, 5 percent receive and 90 percent standby. Range of surface communications, when given, is quite varied and falls between 3 to 25 nautical miles (6 to 46 km). It is safe to assume that the lower end of this spectrum is most representative.

5.1.8 RDF Beacon

Radio beacon signals are used to aid in locating a submersible on the surface through use of an RDF on the surface ship or an aircraft. By definition, all submersibles that carry a radio transceiver have a radio beacon transmitting capability, but this category deals only with those that carry a beacon separate from the radio or those which have radios in which a beacon transmitting capability is a built-in option.

Fifteen vehicles now carry or plan to carry a radio beacon; their operating capabilities vary widely. Most are self-powered and the remainder operate off the main power supply. A few can operate off the emergency power. Frequencies range from 2 mHz to 243 mHz. Operating duration ranges from 12 hours to 120 hours. The majority are activated by the pilot, but a few are automatically activated when the vehicle surfaces.

The Soviet vehicles, PISCES VII and XI carry radio transponders instead of beacons; these are self-powered and of 64 hours duration. Lockheed's DEEP QUEST uses two beacons, one is for emergency use and transmits on 121.5 mHz, which is compatible with Coast Guard aircraft receiving units. The other DEEP QUEST beacon activates upon surfacing and is used as an additional means by the support craft to determine that the vehicle has surfaced.

5.1.9 Surface Lights

This category encompasses all lights external to the pressure hull which are used to visually locate the submersible on the surface and which are designed for operating in air. As a final resort, weather permitting, virtually all submersible pilots can open the hatch and signal with a lantern or flashlight.

Approximately 62 percent of all submersibles carry surface lights. The majority of lights are white, but amber, blue, red and blue-white are also used. Most lights are self-powered; a few operate off the main batteries. In two instances the lights operate off the main and emergency batteries. Operating duration varies from a minimum of 12 hours to a maximum of 168 hours. In one instance, DIAPHUS, the light duration is reported as 15 days. All but one light are of the flashing type and the period or repetition rate varies widely between one flash/second to one flash every five seconds. Three submersibles carry red and green non-flashing lights in addition to a flashing light.

Owing to the low silhouette of all submersibles, the height of the light above the water is small and ranges from one (0.3m) to six feet (1.8m), the average being approximately three feet (0.9m). Visual detection of these lights from a surface craft is dependent, among other things, on the observer's height above

the water. At ten feet (3m) height, the average vehicle is visible at a distance of 3.6 nautical miles (6.7 km); at 20 feet (6m), the distance is 5.1 nautical miles (9.5 km). From an aircraft the distance is multiplied considerably; PC-16's light is reportedly visible from the air at 22 nautical miles (40.8 km).

Activation of the lights upon surfacing is either automatically or manually by the pilot. The operators of SDL-1 report that automatic activation of their particular light (OAR Mod. SF-500-1-100) is not always dependable when operating in cold temperatures. In one particular instance, the light did not commence flashing until the vehicle was back in its shop.

5.1.10 Radar Reflectors

Only nine submersibles (16%) carry radar reflectors. These are equally divided between collapsible corner reflectors that are deployed upon surfacing or those which are permanently affixed to the sail. To enhance its radar reflectivity, the operators of DEEPSTAR-2000 have lined the inside of its fiberglass sail with aluminum foil. Height above the water of the reflectors is from two feet (0.6m) to 6.5 feet (2m).

5.1.11 Rockets/Flares

Distress rockets or flares are carried by 16 submersibles (20%). The number of units carried ranges from one to twenty. The majority are red, one is white, and two vehicles carry both red and white units. SEA OTTER carries a hand-held flare which burns red at one end and white at the other.

All vehicles, but one, store their flares inside the pressure hull. And all vehicles, but two, must open the hatch cover to fire the flare. The exceptions

are the JOHNSON-SEA-LINK I & II where a receptacle has been built in the pilot's sphere hatch cover into which the flare can be placed and activated without opening the hatch cover.

5.1.12 Smoke Signals

Only four submersibles carry smoke signals. A distinction is made herein between distress rockets/flares and smoke signals. The rocket/flare type pyrotechnic, which is fired from the submersible, does not provide the surface observer a signal which is readily traced to its source, because, when it activates, it is at some distance from the submersible. The smoke signal, on the other hand, eminates from - and remains at - the source until expired.

The eight smoke signals carried in DEEPSTAR-2000 are yellow, hand-activated, and stored inside the pressure hull; the hatch must be opened to activate them. The Intersub vehicles, PC-8B, 1201 and 1202, carry black smoke signals which are installed externally to the pressure hull and are electrically activated by the pilot. The black color, obviously, would limit the signal's use to daylight hours only.

The manufacturer of Intersub's smoke signals is Societe PYROMECA (Chemin de la Roquette, 83-Toulon, FRANCE); they are presently conducting a design study for CNEXO of another smoke signal which will emit white smoke for a duration of 15 minutes and will have a submerged depth capability of 6,000 meters (19,685 ft). Illumination is automatic if the flare (vehicle) has been submerged to depths below 50 meters (164 ft).

5.1.13 Marker Buoys

Fifty three percent of all vehicles carry some form of buoy which can be released by the pilot to provide a visual target for rescuers to follow. In its most basic form, the marker consists of a buoy and thin line attached to the submersible. In its most sophisticated form, it consists of an instrumented buoy attached to a line capable of hauling the vehicle to the surface. Within this range are a wide variety of options which are identified below.

No. of Vehicles	Buoy & Line Characteristics
21	Serves as marker only.
5	Serves as marker and telephone link.
6	Serves as marker; line can be used as guide for special retrieval hook from surface.
2	Serves as marker; buoy supports radio beacon, flashing light and acoustic pinger; line can lift vehicle to near-surface.

The color of the buoys varies considerably; orange is most frequent; then, in order of decreasing frequency, red, orange and white, pink, yellow and metallic. The buoy shape is spherical, elliptical, rectangular or square.

Some submersibles, SEA EXPLORER and the MOANA series, eject the buoy from the vehicle where an anchor holds it to the bottom. They may serve the additional role of marking points of interest while the submersible is underway.

The most sophisticated marker buoys are those designed by Hyco for the Soviet PISCES submersibles. The buoys are rectangular shaped blocks of syntactic foam stored atop the submersible and attached to it by several thousand feet of "Phillystran" line. On top of the buoy is a radio beacon and a flashing light;

under the buoy is an acoustic pinger. The line has a breaking strength of six tons (5.4t) and can be used to retrieve the vehicle to near the surface where stronger lines can be attached to bring it aboard.

The emergency buoys on JOHNSON-SEA-LINK I & II are unique in that they are inflated by compressed air while the vehicles are submerged. This arrangement does not affect the weight and balance characteristics of the submersible, nor does the buoy take up a considerable amount of space. Recent tests resulted in the design and installation of a larger buoy to contend with the strong currents of the Gulf Stream which restrained the smaller buoy from surfacing. Pressure relief valves were incorporated in the buoy to prevent it from exploding as it neared the surface and the compressed air expanded.

A few of the shallow diving submersibles, e.g., DIAPHUS, always tow a buoy when diving; this serves for both tracking and emergency purposes.

5.1.14 Life Jackets

All vehicles, but five, carry life jackets. It is a legal requirement of all U.S. submersibles to carry life jackets, but not all comply with this law. All life jackets in submersibles are the inflatable type; these are not Coast Guard approved.

5.1.15 Life Rafts

Only three submersibles carry life rafts: CYANA, DS-2000 and AUGUSTE PICCARD. CYANA and DS-2000 carry three one-person capacity rafts inside the pressure hull. AUGUSTE PICCARD carries two, six-person capacity rafts inside the pressure hull.

5.1.16 Automatic Deballasting

Four submersibles include an automatic deballasting feature that will empty (blow) the main ballast tanks unless the pilot takes preventative action, or if the vehicle exceeds a prescribed depth of water. BURKHOLDER I will automatically deballast every 15 minutes; a buzzer/light warning signal allows the pilot 45 seconds to reset the automatic device before it activates. SHINKAI and MERMAID III & IV are equipped with pressure sensing devices that will automatically blow ballast if they exceed operational depth. On SHINKAI an excess of 30m (98 ft) below operational depth is allowed.

5.1.17 Emergency Breathing

All submersibles include an emergency breathing device to use in case the normal oxygen supply/carbon dioxide removal system fails, or in the event that noxious/toxic gasses permeate the atmosphere. Basically, two systems are employed: open or closed-circuit. Open-circuit systems are those wherein the user draws his air or oxygen from an emergency source and exhales into the pressure hull. Closed-circuit systems are those wherein the user exhales back into the system and a scrubber compound is used to remove carbon dioxide. The open-circuit system results in a pressure build-up inside the hull; the closed-circuit system does not. There is an approximately equal distribution between vehicles using closed-circuit and those using open-circuit systems. Three submersibles carry both open and closed-circuit systems. Whether open or closed-circuit, the nature of emergency breathing systems in submersibles varies considerably. The following summaries are an attempt to organize a most unwieldly subject.

Open-Circuit Systems - Eighty percent of all submersibles using an open-circuit system draw from the vehicles' compressed (deballasting) air supply. Each

occupant is supplied a regular scuba-type mouthpiece which is connected by a high pressure hose having access to the compressed air. The user exhales directly into the cabin atmosphere. Most, but not all, vehicles also supply a face mask for eye protection against smoke. Owing to the small size of the pressure hull, it is not considered necessary to have more than one connection per occupant to the compressed air supply. In AUGUSTE PICCARD, however, there are 26 quick-connect sockets throughout the vehicle and 12 full face masks. Additionally, six scuba sets are carried for back-up and possible egress from the vehicle.

The estimated breathing duration from open-circuit devices drawing off the vehicle's deballasting air varies from 1.2 hours to six hours/user and averages three hours. Significantly, 77 percent of the vehicles using this technique do not specify an operating duration because the amount of air available depends upon the number of deballasting cycles undergone prior to employing the system. A second reason for not having access to the data is simply because the operator does not know how long it will last.

The operators of the Canadian Armed Forces vehicle, SDL-1, conducted submerged tests on the deballasting air system and measured six hours/user. Another result of these tests was significant: the pressure build-up inside the hull at the end of the tests reached three atmospheres of 44.1 psia (3.1kg/cm^2). In addition to decompression considerations, thought must also be given to instruments inside the pressure hull which may implode under pressure and possibly cause the loss of a vital control or indicator.

Closed-Circuit Systems - The most common closed-circuit systems in submersibles are small volume, self-contained (O_2 supply and CO_2 scrubber), and portable

devices manufactured by Drager, Fenzy, Emox or Westinghouse. The duration offered by these systems ranges from 15 minutes to six hours/user; 1.9 hours is average. ALVIN employs a system wherein the oxygen supply and CO_2 scrubber is not portable, but all components are in the hull and easily accessible.

Emergency breathing in the LOC of JOHNSON-SEA-LINK I & II is provided by a portable closed cycle system (Bio-Marine CCR-100), which also provides routine life support when the divers are locked out. Normally the breathing gasses are completely contained within the system with no loss to the surrounding water unless the diver ascends. In the emergency mode, the exhaust side of the breathing hose is disconnected and the user exhales directly through a CO_2 scrubber into the cabin atmosphere. In this mode, no electrical power is required, but the system is now open-circuit and man-powered.

Perry Ocean Products has tested their Emergency Life Support System (ELSS), a man-powered, self-contained system by which the user inhales cabin air and exhales through a CO_2 scrubbing compound. The system offers a full face mask, weighs seven pounds and provides a minimum of 40 hours/user. The ELSS was designed specifically for emergency use in submersibles, diving bells and hyperbaric chambers and is intended to be stored for long periods of time.

5.1.18 Personnel Egress

Approximately 50 percent of all submersibles have some procedure whereby the occupants can open the hatch cover and depart the vehicle underwater. The water depth, according to the operators, from which this can be safely accomplished is somewhat uncertain. Some operators, e.g., the NEKTON series, regard 200 ft (61m) as the maximum depth. Most do not state any particular depth limits, but merely

regard personnel egress as an emergency option if the vehicle cannot ascend. All operators regard this option as a last ditch effort which is only employed after all else has failed and life support is almost expended. The Canadian Government is, however, investigating egress procedures from SDL-1 with 500 ft (152m) as the objective. If this procedure is developed, its objective is to place underwater egress as an acceptable initial procedure, rather than one of desperation.

There are two basic procedures which can be used to bring the pressure differential across the hatch cover to zero: 1) flood the hull with sea water, or 2) fill the hull with compressed (deballasting) air. In a number of vehicles the means are available to employ both procedures concurrently. The problem with either or a combination of both procedures is that within the time it takes to reach a point where the hatch can be opened, the occupants may be required to decompress during their ascent. The individual fortitude required to remain calm and then follow precise instructions to leave the vehicle and ascend-in, perhaps, total darkness and cold - is a quality not readily found in most individuals.

Egress from a lockout vehicle is an established routine and, if the occupants are trained, the procedure is a safe one. Still, if the depth is great enough, decompression may be required. Only a handful of vehicles provide a portable air supply which the occupants can use during surface ascent. In virtually all instances, the procedure is one of "blow and go." If the occupants are fortunate in reaching the surface, the potential problem of thermal protection while in the water waiting for rescuers is a major one because only the lockout vehicles carry wet suits or some form thereof.

Two alternatives to underwater egress are found; the first is in the vehicles ALVIN and SEA RANGER; the second is in the SHINKAI. ALVIN and SEA RANGER are designed such that it is possible to release the entire pressure hull from the vehicle chassis; its positive buoyancy will take the hull and crew to the surface. Calculations show that SEA RANGER's pressure hull would turn upside down when released. For this reason, a second hatch is located on its underside which may be opened on the surface. SHINKAI has a releasable, 1.75m (5.74 ft) diameter, positively buoyant steel sphere attached above its forward sphere. If the vehicle cannot ascend, the crew enters the escape capsule and releases it from the main body.

5.1.19 Lift Points

It is generally accepted that the only feasible means of rescuing the occupants of a submersible which cannot surface is to retrieve the vehicle. At present, the only practical means of retrieval is by attaching a line and hauling it to the surface. For this reason, lift points are considered as emergency devices.

The variations in lift point configurations and dimensions from vehicle-to-vehicle are so numerous that generalizations are pointless. Additionally, the lift point descriptions given in Section 3.0, for those vehicles now under construction, will probably change, for when the vehicle is delivered to the operator, this feature is generally reconfigured to accommodate his launch/retrieval scheme. Consequently, this section is directed more towards pointing out the diversity in lift points rather than the commonality. Another variation is found in the fact that almost all submersibles have a point on the vehicle other than the main lift point where a line can be attached. This secondary point can be a support bar on the exostructure, a hole in the keel or a motor guard where, as a last

resort, something can be fabricated to secure to this point. Such secondary attachment points are not dealt with in this discussion although they are described, in some instances, in Section 3.0.

Configuration - Lift points are circular, elliptical, "U"-shaped, hook-shaped or shackle-shaped. In some instances, e.g., ALVIN and CYANA, they are loops in the end of a steel cable. In others, e.g., Vicker's PISCES, they are configured in a shape resembling - and referred to as - a "Rams Horn." From a secure attachment point of view, any of these configurations are adequate except for the open hook; the reason being that constant tension must always be applied to the lift line after attachment has been made to assure that the lift line does not slacken and fall out. The Intersub vehicles, PC-8B, 1201 and 1202, have avoided this problem by installing a counterweighted bar across the open face of the hook to prohibit the lift line from falling out. PC-9 has the same feature in the form of a metal plate that is placed across the hook opening.

Attachment - Many of the lift points are attached rigidly upright to the vehicle framework. Others are attached such that they can be pivoted downward forward or aft to avoid entanglement. A few are attached by a wire or rope bridle and merely lay on the vehicle's deck when released. In several instances, the lift point can be recessed into the fairing when not in use. In one case, the lift point is not only recessed, but metal plates fold over the recessed lift point which must be opened in order to make an attachment.

The major difficulty in attaching a rescue line to those lift points which lay flat on the vehicle or are recessed into its fairing is that the rescuer must perform two tasks: 1) hold the lift point in an upright position and 2) attach

the retrieving line. These two functions require two manipulators, which many vehicles do not have, and a high degree of maneuverability. In essence, when the lift point is not rigidly upright, the rescuer's task is made much more difficult.

The AUGUSTE PICCARD and SHINKAI present more formidable problems: a bridle must be attached underwater in order to provide a lift point attachment. This situation calls for manipulative dexterity and maneuvering/hovering control to a degree not found in many vehicles. DEEP QUEST presented a similar problem until a line was attached between two of its lift padeyes and fastened upright to a thin cable running from rudder to sail. A retrieving hook can be attached to the line allowing DEEP QUEST to be hauled to the surface. CYANA's operators circumvented this problem by attaching a length of stainless steel wire rope to the main lift point which is tacked to the fairing and terminates on the stern in the shape of a loop. A specially-designed toggle is carried aboard its surface support craft which can be inserted into the loop for retrieval.

Lift Capacity - When the lift point is a single point used for routine launch/retrieval of the vehicle at sea, it will be strong enough to lift the submersible clear of the water and onboard. When the point is one of several to which a bridle is attached on the surface for launch/retrieval, it is probably only adequate to bring the vehicle to some point near the surface where divers can make more substantial attachments. Because the variations in lift capacity are so wide, one is urged to consult Section 3.0 for vehicle-by-vehicle lift capacity data.

The JOHNSON-SEA-LINK I & II present a unique set of circumstances to the rescuer. Both of these vehicles have a specially-designed housing wherein a "drop lock" is inserted which can lift the vehicle to the surface. The drop lock design is

unique to the Harbor Branch Foundation and not carried by any other submersible. The support ships for the JOHNSON-SEA-LINKs each carry a spare drop lock for emergency retrieval.

5.1.20 Manipulators

Approximately 80 percent of all submersibles carry a manipulator; 41 percent of these carry two. Although manipulators are primarily used for various work tasks, they are an obvious and major factor in the retrieval of one submersible by another. Virtually all manipulators are electro-hydraulically powered; a few have variable rate control; none has force feedback.

Degrees-of-Freedom - Present submersible manipulators have from two to six degrees-of-freedom. The two degrees-of-freedom generally includes an elbow (locator) motion (up/down) and a wrist rotation (orientor) motion. The six degrees-of-freedom includes two shoulder motions (up/down; left/right), an elbow motion (up/down) and three wrist motions (up/down, left/right, wrist rotate). In a few instances, linear extension is also included.

Jettisoning - Sixty-three percent of all manipulators can be jettisoned. The Hyco-designed manipulators can jettison the claw, a few can jettison the entire arm, but, for economic reasons, this is not a widespread practice. The claw jettisoning capability is advantageous in retrieving heavy loads, whereby the manipulator grips an object, is then jettisoned, and the vehicle surfaces while reeling out a line attached to the manipulator on its way to the surface. The line is then transferred to the support ship where retrieval commences. Another approach is to tow a line tied to a buoy and to the manipulator. This precludes reeling out on the way to the surface.

Claw Types - A variety of claw types are found on manipulators; the parallel jaws-type is most frequent, then the scissors-type (where one finger locks through the center of two opposing ones). Less popular are the orange peel, the Dorrance and the pincer-type claws. Hyco-designed manipulators (found on all the PISCES class vehicles and the SDL-1) have a scissors or parallel jaws-type claw on the six degrees-of-freedom manipulator. The circular claw may be used to grasp and hold on to an object while the other arm performs work.

The Vickers's submersibles and others have a range of manipulator terminations that can drill, grind, impact, saw or cut. This area of capabilities is advancing so rapidly that it is fruitless to list what each individual vehicle has because capabilities will undoubtedly change by the time this handbook is printed.

Grasping Capacity - The grasping capacity of manipulators is variable. The Hyco-designed circular claw-type manipulator is greatest at 2,000 lbs (906kg); the remainder are generally 100 lbs (45kg) or less. In the manipulative tasks for which they were designed, the low grasping force is satisfactory; as a means whereby one can grasp and bring another submersible to the surface they are, by design, inadequate.

It should be noted that lockout submersibles carry the finest manipulators yet designed: the diver's hand. However, the depth of operation is limited to slightly over 700 feet (213m) - the deepest lockout depth to date.

5.1.21 Fire Extinguishers

U.S. submersibles are required by law to carry a hand-portable (B-1 type), fire extinguisher when no fixed fire extinguishing system is installed in machinery spaces. All submersibles, but five, carry fire extinguishers. All but six of

these are dry chemical extinguishers; the exceptions are found aboard the U.S. Navy submersibles which use carbon dioxide and GRIFFON which carries distilled water. Preliminary investigation of distilled water as a fire extinguisher indicates that, at the low voltages (less than 40) inside submersible pressure hulls, distilled water will not only do the job safely, but will not damage electronic equipment as does the dry chemical type. Further, it might serve as an emergency source of drinking water if changed or checked at frequent intervals.

5.2 Classification/Certification

With one exception, there are no laws governing the design, construction or operation of present submersibles. The exception is AUGUSTE PICCARD, whose size and method of operation places it in a category for which the Canadian Ministry of Transportation has regulations. Certain equipment requirements for US manned submersibles are delineated under the Federal Boat Safety Act of 1971. Because submersibles vary widely in their design and operation, the operator, in order to comply with these requirements, must contact the nearest Coast Guard Officer in Charge of Marine Inspection. These Federal requirements cover: certification numbers, validation stickers, personal floation devices, fire extinguishers, whistles, bells and lights. Inflatable life jackets are not currently Coast Guard approved. This is significant because every submersible operator who provides life jackets (personal floatation devices) uses an inflatable type.

At least nine bills have been introduced to Congress to regulate submersibles, but none have passed. The operators and builders, however, have voluntarily built their vehicles to a standard. The standard has been one of several

classifying agencies or a certifying branch of one of the federal governments. Of all the presently operating vehicles, only nine have not been either certified or classified, and all of those now under construction have applied for certification or classification.

5.2.1 Certification (Self-imposed Standards)

All U.S. Navy submersibles must be certified in accordance with the Navy Material Command's "System Certification Procedures and Criteria Manual for Deep Submergence Systems" (P-9290, July 1973). Both GRIFFON and SHELF DIVER are maintained to French Naval standards. SDL-1 was ABS classed initially and is now maintained to Canadian Armed Forces standards. The URF is being constructed according to standards developed by the Swedish Navy.

5.2.2 Classification

There are three private activities that have classified manned submersibles: The American Bureau of Shipping (ABS), Germanischer Lloyds and Lloyds Register of Shipping. Det Norske Veritas issued their "Tentative Rules for the Construction and Classification of Submersibles 1974," but no submersibles have used this classification at present.

The most active classification activity has been ABS. All presently-operating Perry-built and Hyco-built submersibles are ABS-classed. All vehicles now under construction are building to a classification activities standard and ABS is the one most used.

ABS is in the process of finalizing a "Guide for the Classification of Underwater Vessels and Related Systems," an underwater vessel is tentatively defined as a manned or unmanned submersible, a habitat, a work chamber, a transfer capsule or as a decompression chamber. No publication date has been announced for the new ABS guide.

5.3 Support Vessels

All submersibles which operate in the open ocean do so with an accompanying support vessel. In every instance, but AUGUSTE PICCARD, the support vessel launches and retrieves the submersible for each dive, and further serves in various ways to maintain the vehicle and crew and support the undersea operations. Diving activities in protected bays, lakes and other inshore waters are pursued more modestly, where a rubber raft and outboard motor may be all that is considered necessary.

Support vessels vary in design and size. Most are conventional hulled vessels, but a few are catamarans and one is a motorized barge-like hull. The size and displacement varies most. Table 5.2 presents various characteristics of presently-operating support vessels. Of the ten vessels now operating in the North Sea, four are less than 200 feet (61m) LOA; the remainder are from 265 feet (81m) to 354 feet (108m). Not included in Table 5.1 are the two new Intersub support ships, INTERSUB THREE and INTERSUB FOUR. Both are 1,600 gross tons; the former will support PC-1202, the latter will support PC-16.

Many of the support vessels shown in Table 5.2 are not owned by the submersible operating company, but are under lease. A trend can be seen with the Vicker's support vessels towards supporting two submersibles concurrently. All open ocean support vessels in the temperate and high latitudes are equipped with enclosed shops in which maintenance/repair work is conducted. No support vessel carries an emergency retrieval system onboard, however, most operators are aware of other submersibles or unmanned devices which are available and could be rapidly brought into play in the event of an emergency.

TABLE 5.2 SUBMERSIBLE SUPPORT SHIP CHARACTERISTICS

NAME	LOA (ft/m)	BEAM (ft/m)	DRAFT (ft/m)	GROSS TONNAGE	CRUISE SPEED (kts-km/hr)	CRUISE RANGE (nm/days)	LAUNCH/ RETRIEVAL SYSTEM	COMMUNICATIONS (SHIP-TO-SHORE)	NAVIGATION	REMARKS
AKADEMIK KURCHATOV	400/122	56/17	15/4.6	6,681 (displ)	19-35	NA	None at present	NA	NA	
BALDER DIVER	217/66.3	34.7/10.6	15.4/4.7	1,653	14.5-26.9	10,000/60	Telescoping crane	SSB, VHF	Decca Hi-Fix, RDF, Radar, Gyrocompass	
BAY SHORE	185/56.4	37.5/11.4	13.5/4.1	1,499	14-25.9	15,000/NA	Stern A-Frame	R/T, VHF	Decca 21, Radar, Gyrocompass	
BRUKAMARAN	45.9/14	29.5/9	2.3/0.7	36 (displ)	6-11.1	NA/1	Overhead A-Frame	CB	Visual	Catamaran, daily ops. only.
CAPALONGA	354/108	49/15	19.3/5.9	5,000	14-25.9	10,000/30	Stern A-Frame	UHF, VHF, SSB	Decca Hi-Fix, Gyrocompass	
DMITRI MENDELEEV	400/122	56/17	15/4.6	6,681 (displ)	19-35	NA	None at present	NA	NA	
GYRE	174/53	36/11	12.5/3.8	292	11-20.4	8,000/21	Stern A-Frame	SSB, CB	RDF, Radar, Loran A&C, NAVSAT, Omega ULF	
HUDSON HANDLER	90/27	38/11.6	9.75/3	340	6-11	15,000/30	Hinged ramp	VHF, SSB	RDF, Radar, Decca, Loran	Barge type hull
JOHNSON	124/37.7	24.5/7.5	8.75/2.7	210	12-22.2	7,200/14	Articulated crane	SSB (2 ea.), AM, VHF	Radar (2 ea), Decca 914 & 916, Gyrocompass, Loran DAL-222	Decompression facility to 350 psi (24.6kg/cm^2)
LULU	98/30	48.14.6	9/2.9	350 (displ)	6-29.6	1,200/	Cradle	AM, VHF, SSB	Loran A, Radar	Catamaran
MAXINE "D"	162/49	38/11.6	11/3.3	198	11.5/21.3	60,000/60	Non-articulated crane	HF (3 ea), VHF	SATNAV, Loran c, Radar, RDF, Gyrocompass	
NADIR	182/55.6	39/11.9	15/4.6	978	12-22	7,500/30	Stern A-Frame	VHF, Telex	Radar, Decca Navigator, Gyrocompass, RDF	
NEPTUNE	115/35	34/10.4	4/1.2	350	7-12.9	500/14	Non-articulated crane	VHF/FM	Radar	
NEREUS	112/34	28/8.5	8.5/2.6	219	11.5-21.3	4,000/30	Articulated crane	CB, SSB, VHF	Radar, Loran A	

TABLE 5.2 SUBMERSIBLE SUPPORT SHIP CHARACTERISTICS

NAME	LOA (ft/m)	BEAM (ft/m)	DRAFT (ft/m)	GROSS TONNAGE	CRUISE SPEED (kts-km/hr)	CRUISE RANGE (nm/days)	LAUNCH/ RETRIEVAL SYSTEM	COMMUNICATIONS (SHIP-TO-SHORE)	NAVIGATION	REMARKS
OTOME MARU	139/42.3	25/7.5	8/2.4	406	11.4-21.1	900/NA	Towed	SSB, VHF, MHF, CB	Radar	Operations limited to 20 nm (37km) from shore.
PANDORA II	191/58	45/13.7	15/4.6	1,377	10.5/19.5	25,200/100	Stern A-Frame	HF (2 ea), VHF	Radar, Gyrocompass, Loran A&C	
POINT LOMA	465/142	74/22.5	20/6.1	12,430	10-18.5	NA/90	Decking Well Lift	HF, UHF, MF	Loran A&C, Radar, Gyrocompass, SATNAV	Undergoing refit (5/13/76).
PROTEE	248/76	35/11	18/5.4	1,984	12.5-23.2	10,000/60	Stern A-Frame	SSB, UHF, VHF, Telex	Radar, Gyrocompass, RDF, Decca Hi-Fix	
ROBERT GIRAUD	256/78	27.9/8.5	11.5/3.5	1,323	14-25.9	6,800/NA	Articulated Crane	HF, UHF, VHF	Loran, Ragep, Toran	
SEA DIVER[1]	94.7/28.8	22/6.7	9.7/2.9	268	8.5/15.7	4,000/30	Articulated Crane	CB, AM, VHF, SSB	Radar (2 ea), Loran	
SEA DIVER[2]	170/52	37/11.3	12.5/3.8	927	12-22.2	10,000/30	Stern A-Frame	VHF, Telex	Radar, Decca Navigator, Gyrocompass	
SEA STORK	172/52	36/10.9	11/3.9	632	12-22	4,700/30	Stern A-Frame	VHF, Telex	Radar, Decca Navigator, Gyrocompass, RDF	
SUBSEA I	265/80.7	42/12.8	15.75/4.8	1,499	14-26	1,500/90	Stern A-Frame	VHF, SSB, HF	Loran C, Decca, Radar	Two submersible capability.
TRANSQUEST	108/33	39/11.8	7/2.1	400	6-11.1	1,100/10	Cradle	VHF, MF	Loran A&C, Radar, Gyrocompass	
VICKERS VANGUARD	269/82	44.7/13.6	17/5.2	3,000 (displ)	14-26	6,000/30	Stern A-Frame	VHF, RT, WT	Decca MK 21, ATNAV	Two submersible capability.
VICKERS VENTURER	122/37	25.1/7.6	15/4.6	640 (displ)	9-16.7	1,800/10	Stern A-Frame	VHF, RT	Decca Navigator	
VICKERS VIKING	266/81	44/13.4	20/6.1	3,000 (displ)	14-26	6,000/30	Stern A-Frame	VHF, RT, WT	Decca Mk 12, ATNAV	
VICKERS VISCOUNT	275/84	42/12.8	17/5.2	3,400 (displ)	14-26	7,200/30	Stern A-Frame	VHF, RT, WT	Decca MK 21, ATNAV	Two submersible capability.
VICKERS VOYAGER	274/84	48/14.6	22/6.7	4,500 (displ)	12.5/23	6,000/30	Stern A-Frame	VHF, RT, WT	Decca MK 21, ATNAV	Two submersible capability.

1. Harbor Branch Boundation
2. Intersub

A breakdown of the support ship crew, submersible crew and accommodations for supernumeraries is presented in Table 5.3. M/V CAPALONGA is used for work tasks other than support of PS-2; hence, the large number of accommodations for supernumeraries.

5.4 Launch/Retrieval Systems

All launch/retrieval systems now in use follow the same general procedures: 1) attach a tugger line to the vehicle (usually by a swimmer); 2) pull the submersible to a point where a lift line can be attached; and 3) lift the vehicle out of the water and aboard ship. The first two steps do not vary considerably from vehicle-to-vehicle, but the configuration of the lifting device does. Table 5.2 identifies the various configurations which are regularly employed for launch/retrieval. Fifty eight percent (14 vessels) of the support ships employ a stern-mounted A-frame; the remainder are almost equally divided between other arrangements. Significantly, 12 out of the 14 vessels with a stern A-frame work the North Sea and its environs. Of the remaining two, one (PISCES IV) works the Arctic and the other (DIAPHUS) works the Gulf of Mexico. With the exception of HUDSON HANDLER (Hyco Subsea vehicles) and, possibly, BALDER DIVER (COMEX vehicles) all the remaining handling systems are used in the temperate and tropic latitudes.

While several submersibles may use the same general approach to launch/retrieval, there are vehicle-to-vehicle variations within each approach. What follows, therefore, is a description of the general approach with comments regarding operator variations within the general category.

TABLE 5.3

SUPPORT VESSEL CREW AND SUPERNUMERARY ACCOMMODATIONS

VESSEL	SHIP CREW	SUB. CREW	SUP. ACCOM.
BALDER DIVER	16	10	5
BAY SHORE	10	NA	22
CAPALONGA	30	8	70
GYRE	10	NA	19
HUDSON HANDLER	6	3	1
JOHNSON	11	5	10
LULU	9	11	19
MAXINE "D"	7	12	7
NADIR	17 (total sub & ship)		4
NEPTUNE	7	6	0
NEREUS	8	6	0
OTOME MARU	12	12	8
PANDORA II	18	6	12
PROTEE	18	10	7
ROBERT GIRAUD	60 (total sub & ship)		21
SEA STORK	17 (total sub & ship)		4
SUBSEA I	18	30	10
TRANSQUEST	7	12	11
VICKERS VENTURER	13	NA	17
VICKERS VIKING	22	NA	24
VICKERS VISCOUNT	24	NA	20
VICKERS VOYAGER	29	NA	20

5.4.1 Overhead A-Frame

This system is used only in sheltered areas by Bruker-Physik AG from aboard a catamaran. The A-frame forms the connection between the two hulls and sustains all forces generated during launch/retrieval. A six part block and tackle, powered by an electric winch of 12t (13.2 tons) capacity, performs the launch/retrieval chores. The submersible (MERMAID series) is driven in between the two hulls where connection is made to the lift point. The vehicle is then lifted to deck height and a hydraulic guide-rail system can be available to steady the submersible. The system is advertised for use in coastal (i.e., sheltered) waters only.

5.4.2 Non-Articulated Crane

A 20 ton (18.1t) capacity hydraulic crane is used to launch/retrieve PC-14C-2. The operation is simply to lift the submersible into or out of the water by a single point pickup. Two steadying lines (one forward and one aft) are employed. The steadying lines and main lift hook (a standard snap hook on a nylon hawser) are attached by a swimmer after the submarine has maneuvered alongside NEPTUNE. Because there is a long length of line and cable between the leading edge of the crane and the submersible, the pendulum effect can be tremendous at very low sea states. Without a large number of steadying lines, this system is impractical for places other than the sheltered waters of Kwajalein Atoll where PC-14C-2 operates.

SEA CLIFF and TURTLE are the heaviest operating vehicles which are routinely launched and retrieved for each dive, and the only other vehicles which regularly use a non-articulated crane. The crane is hydraulically-powered and rated at

100 tons (91t). It is located on the stern of MAXINE "D" and, after picking up either vehicle, rotates to the port side for launch and subsequent retrieval. There are four lift points on each vehicle; two are inside the sail, one is amidships and one on the stern. For launching, an "I" Beam, suspended from the main lift cable by a two-point bridle, is oriented above the vehicle where four cables (two forward, one amidships, one stern) hanging from the beam are attached to the submersible. To obtain steadiness, seven lines are employed: three steady the "I" Beam; two steady the submersible from the MAXINE "D" and two more steady the submersible from an auxiliary craft which is launched prior to the dive and is in position for the submersible launch. The submersible's hatch is closed during launch and the passengers (pilots and observers) do not embark until the vehicle is in the water. When the submersible is in the water, swimmers detach the beam. Then, the support ship's lines are cast off and the auxiliary craft tows the vehicle clear of the MAXINE "D" until it reaches a safe distance and its lines are then cast off. Retrieval is the exact opposite sequence of launch and 20 to 25 minutes is required for each evolution. A light Sea State 4 is reportedly the limit for recovery; however, launching would not be performed much beyond Sea State 2.

5.4.3 Articulated Crane

Four support vessels use an articulated crane for launch/retrieval. The R/V JOHNSON's system will be considered as representative of this group in that R/V SEA DIVER and M/V NEREUS follow essentially the same procedures. No details were available on launch/retrieval from the ROBERT GIRAUD, but its general procedures (except for lift point attachments) cannot vary considerably from those which are described below.

The handling system of R/V JOHNSON consists of one hydro crane, two vertical capstans, a battery pod footprint, two aluminum pipe back stops with gates that can be moved through 90 degrees to accommodate an inner and outer tie-down position, two vertical supports to support the after end of JOHNSON-SEA-LINK, and various padeyes, chains and turnbuckles for securing JOHNSON-SEA-LINK to the deck.

The hydro crane was designed principally for the launch and retrieval of the JOHNSON-SEA-LINK over the stern of a small ship. It is constructed entirely of aluminum alloy 6061-T6 welded with 5356 electrode and is a 100 percent hydraulically-operated system. Incorporated in the crane head is a hydraulic braking system that dampens roll and pitch of the suspended load when it is in housed position.

The crane power is provided by a Vickers 105 G.P.M. pump driven by a 250 hp Volvo diesel engine. The crane hydraulic power can be cross-connected with the forward hydraulic system which furnishes power to the bow thruster, anchor windless and cargo crane. The crane maximum hydraulic pressure is 2,500 psi (176kg/cm^2) and the brake maximum hydraulic pressure is 1,000 psi (79kg/cm^2). The lift cable is 7/8 inch (2.2cm) diameter, 6 x 25 IWRC, extra improved plow steel, pre-stretched, right regular lay, bright finish with a breaking strength of 80,000 lbs (36,288kg). The average pick-up velocity is 1.4 ft (0.5m) per second.

The retrieval procedure begins when JOHNSON-SEA-LINK surfaces and holds a heading into the sea while the support ship makes an approach starboard side to.

When the support ship is approximately 45 feet (14m) from the JOHNSON-SEA-LINK, a swimmer attaches a line to the port quarter of the submersible and then climbs aboard. The support ship maintains minimum turns on the port screw until the vehicle is winched into position and the lift connection is made. The JOHNSON-SEA-LINK falls in behind the surface ship and is winched into position behind the stern until the bow line is snubbed off at the proper distance. A line is passed to the surface swimmer and attached to the stern of the submersible. The JOHNSON-SEA-LINK is then winched in parallel to the stern of the support ship. When the bow and stern lines are snubbed off as marked, the JOHNSON-SEA-LINK is in a position such that the cable and the JOHNSON-SEA-LINK lift point can be guided together by the swimmer and Operations Director. As soon as the attachment is made, the support ship's port screw is taken out of gear, the swimmer swims towards the recovery line and the crane operator lifts the JOHNSON-SEA-LINK out of the water. The support ship's port screw is then engaged and holds position into the sea until the JOHNSON-SEA-LINK is secured on deck.

The attachment point on the submersible is referred to as the drop-lock quick release (DLQR) body; it is a rectangular housing bolted around the submersible strong-back and provides a lifting point near the centers of gravity and buoyancy. At the end of the lifting cable is a torpedo-shaped device called the Drop Lock which fits into the DLQR body. Four flukes on the side of the Drop Lock fall open when it is inserted into the body. When tension is applied to the cable, the flukes make contact with a rim inside and at the top of the body. This provides the lift. To release the Drop Lock, the cable is slackened and high pressure air is piped into the DLQR body from the pilot's sphere. Both hook-up and disconnect are accomplished in seconds. Launch/retrieval of JOHNSON-SEA-

LINK can be accomplished in Sea State 4 with an 11 ton (9.9t) load and in Sea State 5 with a 10 ton (9.1t) load.

5.4.4 Hinged Ramp

HUDSON HANDLER is the only support vessel known to use the hinged ramp system. One module of the vessel is hinged along its foremost transverse, the hinge point being almost exactly midway between the vessel's stem and stern. The module is watertight and contains internal subdivisions. When filled with air, its deck line is horizontal and co-planar with the deck level of the vessel. When partially flooded, the stern end sinks some 17 degrees leading into the water. The deck is fitted with rails and a carriage into which the skids of the submersible fit. The carriage is moved along the rails by a winch and drag line arrangement. When the submersible is on board the support vessel, the carriage is fully forward and locked rigidly in place. To launch the submersible, sufficient water is allowed to flood into the ramp section to submerge its stern end some ten feet below the surface.

The carriage is allowed to run aft until the submersible floats free. To recover, a line is used to haul the submersible into the carriage which is then drawn fully forward. The water is blown out of the ramp section which then returns to the horizontal.

The stern end of the ramp section is restrained by shock absorbing preventers which, while protecting the ramp from damage, permit it to synchronize relatively well with prevailing wave action. Recoveries in seas with wave amplitudes of up to 11.5 feet (3.5m) have been accomplished, but these are not routine; sea state 4 is the normal recovery limit.

5.4.5 Cradle

ALVIN and DEEP QUEST are two of the heaviest vehicles in the field today, weighing 16.1 tons (14.6t) and 52 tons (47t), respectively. Their weight and construction is such that there is no single point on either vehicle by which they can sustain their own dry weight when out of the water. Consequently, for open ocean work, a catamaran-type hull (partial in TRANSQUEST's case), inside which a cradle carrying the vehicles is lowered into the water, serves as the launching/retrieving apparatus. The cradle system employed by ALVIN, which will serve to represent both vehicles, is a cradle suspended by four chains amidships between the hulls which are motor-driven and tested to 30 tons (27t).

The launch and recovery of the DSRV ALVIN is a joint effort of the Master of the DSRVT LULU, the Surface Controller and the Pilot in Command of ALVIN. The Surface Controller has coordination control and is responsible for the conduct of the operation, which includes the DSRV, the DSRVT, plus any additional support units involved. During the actual launch and recovery operations, while the DSRV is on the launch cradle or between the hulls of the DSRVT, the Master of the DSRVT is responsible for the evolution as well as the command of the ship. As the DSRV passes from between the hulls, the Surface Controller assumes operational control of the DSRV and the DSRVT. Line handlers and swimmers receive commands directly from the Pilot in Command (PIC) or the Launch Pilot of the DSRV,who also is responsible for maneuvering the DSRV, as necessary to execute the launch or recovery. A qualified person is assigned to the cradle hoisting controls who is familiar with the system and with possible emergency actions.

When all stations have been manned for launching and agreement has been reached between the DSRVT Master, Surface Controller and PIC that everything is in readiness, the order is given to stand-by to launch the vehicle. At this time, the submersible is unmanned with the hatch shut. When ready, the order is given to lower the vehicle. The hoist system operator and the line handlers take their directions from the PIC. When the cradle is submerged and, just prior to the vehicle being waterborne, the PIC directs the hoist operator to stop lowering. The PIC then boards the submarine and opens the hatch. The observers then enter the submarine. Because of ALVIN's low freeboard, and the possibility of water splashing into the sphere and causing electrical grounds, it is normal procedure, at this point, for the entire crew of ALVIN, including the PIC, to enter the sphere and shut the hatch. An off-duty pilot will board ALVIN and take over the topside duties of PIC for the launch. When ready, the Launch Pilot directs the hoist operator to continue lowering the cradle until the vehicle is waterborne and the cradle is well clear or about 10 feet (3m) below the vehicle. After maneuvering the DSRV well clear of the DSRVT, the Launch Pilot returns control of the DSRV to the PIC. If, in the judgement of the Expedition Leader and the PIC, it is safe to do so, the launch may be carried out by the PIC, with the hatch open. This will normally be done only under conditions of very low sea state.

When the submarine has arrived on the surface for recovery, the DSRVT Master passes the word to stand-by to recover the submarine. When all stations have been manned and the DSRVT is on the proper heading (normally down-wind) the hoist operator is directed to lower the cradle. The small boat may carry an off-duty pilot to the DSRV where he will assume topside control for the recovery.

If, in the judgement of the Expedition Leader and the Surface Controller, it is safe to do so, however, the PIC may open the hatch and come topside to carry out the recovery himself. This will be done only under low sea state conditions. When everything is in readiness, the Recovery Pilot commences his approach. The line handlers and the hoist operator will take commands directly from the Recovery Pilot during the recovery. When the vehicle has been positioned over the cradle, the Recovery Pilot directs the hoist operator to raise the cradle. After the vehicle has landed on the cradle and the vehicle draft is about six feet (1.8m), the Recovery Pilot directs the hoist operator to stop the hoist. The observers, co-pilot, PIC and Recovery Pilot then disembark and the hatch is shut. The PIC then directs the hoist operator to hoist away and the cradle is stowed on its chocks. The submersible is gripped down as soon as possible after the cradle reaches the stowed position.

Launch and recovery of ALVIN is limited to Sea State 4 during routine operations. However, if rough weather moves in on the operation during the dive, special precautions can be taken to conduct retrieval at State 5.

5.4.6 Telescoping Crane

The only vessel employing a telescoping crane for launch/retrieval is BALDER DIVER; its system is designed for support of COMEX's MOANA series submersibles. The crane base is located on the stern where the boom is extendable outboard 6.7 meters (22 ft) from the centerline of the base. The crane length can be telescoped (extended) an additional 3 meters (9.8 ft) outboard if required. The crane is trainable and may move vertically upward from the horizontal and 360 degrees in azimuth. It has a hoisting capacity of 16 metric tons (17.6 tons) and accumulators to maintain constant tension on the lift cable. At the time

of this survey, precise details for the launch/retrieval from BALDER DIVER had not been prescribed, but the general retrieval scenario is outlined below.

The support ship maneuvers to a position where the submersible is off the stern and under the leading edge of the crane (which is in the horizontal plane). A swimmer attaches the main lift cable to the submersible and it is hoisted out of the water until its lift connection (resembling a male fitting) is firmly engaged in the outboard edge of the boom (a female housing). At this point the keel (battery pod) of the vehicle is approximately 0.5 meters (1.6 ft) above the water surface, and at any point is no closer to the support craft than 2.9 meters (9.5 ft). The submersible is then lifted to clear the deck and swung 180 degrees to be placed on an upper deck trolley/rail system which transports it into an enclosed deck house. Launching will follow the same procedure, except that no swimmer is required to release the lift cable. The connection between lift cable and submersible is such that the pilot can release the attachment by turning a handle inside the pressure hull. No Sea State limitations were quoted at the time of this survey, but up to and including a State 4 is envisioned.

5.4.7 Stern A-Frame

The most widely used device for launch/retrieval is the stern-mounted A-Frame. All vehicles operating in the North Sea employ this method. The heaviest submersible using the A-Frame method are VOL-L1 and PC-1202, both with a dry weight of 15 tons (13.6t). The stern A-frame technique for handling heavy loads at-sea has been used for some number of years by oceanographic ships, but Vickers Oceanics Ltd. was the first to utilize it as a submersible handling system.

Basically, this configuration consists of the A-Frame and a smaller, inverted A-Frame or pendant which can pivot fore or aft within the main frame. Depending on the support vessel, the A-frames in use are rated at 10, 12, 14, or 18 tons (9.1, 10.8, 12.7, 16.3 metric tons). Dynamic loading capacity for the 10 and 14 ton frames is 24 metric tons (21.7t). The main frame is extended outboard over the stern or retracted inboard by hydraulic rams. The lift hawser consists generally of a 5-inch (12.7cm) braided nylon line attached to an inboard winch which passes over a roller at the top of the "A" and then downward through an opening in the apex of the pendant.

The success of the A-frame system resides in the nature of the inboard (lifting) winch. The Vickers winch, which is representative of the state-of-the-art, has hydraulic accumulators fitted to it that make stored energy continuously available to a small, low torque, potentially high speed motor. In the event that the submersible experiences wave-induced upward motion, the high speed motor can overrun the main winch motors and maintain a taunt line when the upward motion of the submersible exceeds the normal hoisting speed. This prevents shock loads from being applied to the system.

A variation on this approach is seen on PANDORA II where the lift winch may operate in three modes:

1. Lift Tension - the winch lifts the vehicle straight out of the water.
2. Hoist Tension - the winch operates similar to that described for the Vickers system.
3. Free Tension - the winch automatically pays line in or out in accordance with the wave-induced motion of the submersible.

The main components described above (A-frame, pendant, lift hawser and winch with accumulators) are common to virtually all stern A-frame systems, but the attachment points and attachment/retrieval techniques vary from operator-to-operator. The variations amongst the three major North Sea submersible operators (Vickers Oceanics, P&O Subsea,Ltd, Northern Offshore, Ltd.) are discussed below. These discussions deal with the process of retrieval; launching follows the reverse procedure.

Vickers Oceanics Ltd.: Upon surfacing the submersible, the support ship positions itself approximately 100 ft (30m) from the vehicle. An inflatable rubber raft carrys a diver and the end of a braided nylon tow line to the submersible. Reaching the submersible, the diver attaches the tow line to the stern of the PISCES vehicle and then climbs aboard and into the sail. The support ship gets underway into the prevailing seas at a speed between 1 to 2 knots (1.8-3.7 km/hr), or whatever is adequate to maintain headway when the submersible is under tow. The submersible is drawn close to the stern by its tow line to a point where the lift hawser can be attached to the lift hook by means of a conventional shackle. The submersible is then lifted by the winch until it is almost two-blocked to the pendant frame. The diver, who rides on the submersible throughout the retrieval procedure, then engages a double-looped, safety strap (wire rope) to a "rams horn" lift hook and the braided nylon lift hawser is lowered until the safety strap supports the full load of the vehicle. The main A-Frame is then retracted inboard and the submersible is lowered onto a deck trolley where it is trundled into its shop. The original tow line becomes a steadying line during the retraction phase of the launch procedure. Vickers Oceanics states that operations can be conducted up to - and including - Sea State 6 with this system.

P&O Subsea Ltd.: Retrieval of PC-9 is conducted bow-first instead of stern-first. Similarities to the Vickers approach exist in the use of a small craft, swimmer and tow line to conduct the same initial hook-up functions. The submersible is drawn to a point near the support craft's stern where connection of the main lift hawser can be made. On the P&O system, however, the pendant differs by having a small platform or basket surrounding its apex. This cage is occupied by a crewman who attaches (or detaches) the main lift hawser, to the submersible. The leading edge of the hawser terminates in a loop by which the crewman "lassos" the fishhook-shaped lift point. When engagement is made, the lift line is reeled in to firmly engage the submersible against the leading edge of the pendant. At this point, a steel bar is slid across the opening of the lift hook which takes the strain of the vehicle. Two other aspects of the P&O system are unique; these include:

1. Post-like metal plugs located fore and aft of the lift point attachment; these mate with (female) housings in the basket and serve to limit yawing and pitching of the vehicle when it is lifted.

2. Rubber bumpers are located port and starboard of the lift point; these interface securely with two similar bumpers on the basket and serve to limit roll.

Once the submersible is secured to the pendant, retrieval takes place similar to the Vickers system. The tow line is again used to help steady the vehicle, but its assistance is not as critical. P&O guarantees launch and retrieval up to Sea State 5.

Northern Offshore Ltd. (Intersub): This system does not include a pendant in its A-frame handling device, but does follow the same general operating procedures to bring the vehicle into a position near the support craft for attachment of the main lift line (i.e., rubber raft, swimmer, tow line). During the towing phase, conducted while the support craft is underway, a small parachute is deployed from the submersible. The purpose of the parachute is to act as a drogue and provide dynamic stability. At a point directly under the extended A-frame, the lift hawser is attached by the swimmer. Because there is no pendant, there is approximately 9 feet (2.7m) of lift hawser between the top of the A-frame and the lift point and the pendulum motion induced by Sea State can be severe. To limit this motion, the swimmer attaches four smaller lines to the submersible, two port and two starboard, which are controlled aboard the support craft and serve to steady the submersible as it is brought aboard. The A-frames used in these systems are rated at 10 (9.1t) and 14 tons (12.7t) and have a dynamic loading capacity of 24 tons (21.8t). The lift points on the submersibles consist of a standard hook configuration. The hook opening is closed by a counter-weighted bar that is opened to attach the main lift line. The system can operate routinely in Sea State 4, but retrieval is possible in Sea State 5 if necessary.

There are other users of the A-frame system besides those of the North Sea. Texas A&M University's R/V GYRE uses this configuration to launch/retrieve DIAPHUS, as well as for taking sediment cores. The frame's static lift capacity is 5 tons (4.5t). A 2 inch (5cm) diameter, twisted dacron line is used as the lift hawser. The lift winch does not have accumulators to prevent shock-loading, but operations are planned for - and conducted within - weather conditions that do not present this problem.

Retrieval of DIAPHUS commences when the pilot maneuvers the submersible some 30 feet (9.1m) from the stern of GYRE. At this point, a swimmer, accompanied by a rubber raft, attaches a bow and stern line, and the submersible is drawn to the stern by tugger winches aboard GYRE. The submersible is drawn to a point beneath the extended frame where it is perpendicular to the longitudinal centerline of the support craft. The outboard extension of the A-frame is 4.5 feet (1.4m). DIAPHUS's greatest beam measurement is 6.5 feet (2m). Consequently, there is only 1.25 feet (0.4m) separation between the submersible and the support craft when the vertical lift begins. Rubber tires and bumpers are hung over the transom to cushion the contact between submersible and support craft when it is drawn snugly to these for retrieval. The submersible is lifted clear of the water until it is two-blocked against the freely-swinging metal pendant. The bow and stern lines are then used as steadying lines and the A-frame is retracted inboard. DIAPHUS remains in an atwartship orientation and is lowered onto a cradle immediately inboard. Retrieval in waves of 4 feet (1.2m) height is considered the operational limit of this system. Texas A&M also owns a portable launch/recovery system designed by Perry Oceanographics. The system, however, has not been operationally employed.

5.5 Subsurface Navigation

The present devices and techniques employed to determine a submersible's underwater position vary widely. Several submersibles provide nothing more complicated than a towed buoy which is tracked by the support ship. The position of the buoy relative to the support ship is accepted as the submersible's position. On the other end of the spectrum, are the submersible operators who

acoustically locate and track the vehicle relative to a network (at least three) of bottom-mounted transponders. Somewhere between these two extremes are the operators who acoustically track a pinger on the vehicle from the surface using a directional hydrophone (to obtain relative bearing) and/or an interrogator on the support craft which obtains slant range from a transponder mounted on the submersible. An alternative is found in the application of Doppler sonar, a dead-reckoning system, on the submersible to provide an x-y plot of the vehicle's track.

The present state-of-the-art in undersea navigation or positioning is represented by the bottom-mounted transponder network. While the other systems do offer an indication of the vehicle's position, they do not represent the position accuracies that are obtainable and are being obtained for maximum position location.

Three firms produce transponder navigation systems which are used by presently operating submersibles and unmanned vehicles: AMF, L'Electronique Appliquee (ELA) and Mesotech. The AMF system is, by far, the most widely employed; it is used by many of the North Sea operators, the Canadian Armed Forces and the U.S. Navy. The ELA system is used on the submersibles of COMEX, International Contractors, Inc., and the French Navy. The Mesotech system is used by the AUGUSTE PICCARD and Mesotech components are used for positioning the unmanned TROV.

5.5.1 The AMF ATNAV System

The ATNAV (Acoustic Transponder Navigation) System is produced by AMF Electrical Products Development Division, Sea-Link Systems, Alexandria, Virginia. The

ATNAV hardware consists of four underwater transponders (three are bottom-mounted; one is on the submersible) and surface support craft equipment consisting of a Command/Interrogator and Ranging Receiver, a mini-computer, a teletype, an x-y plotter and interface electronics. With these components, a real-time, continuous x-y plot and x-y-z printout of the surface craft and the submersible relative to the three bottom-mounted transponders is provided. Coverage within an area as great as 50 square miles (130 km^2) is possible and the submersible's position (relative to the transponders) and the surface craft is attainable to $\pm$3 ft (0.9m), depending upon the accuracy of water sound speed and surface ship velocity data.

To begin the at-sea procedures, the bottom-mounted transponders are installed and rough (surface) estimates of their positions are put into the mini-computer. The surface craft then cruises over the transponder network and interrogates the transponders at 10 to 15 random locations. The onboard surface equipment now has the capability of determining the transponder position relative to each other to within approximately $\pm$ 2 feet (0.6m).

The navigation operation begins with interrogation of the bottom transponders from the surface craft. Each transponder replies individually to the surface; there their slant range from the ship is automatically determined. Immediately after, the transponder on the submersible is interrogated. The reply from the submersible transponder performs two functions: 1) it permits determination of the slant range from submersible to ship, and 2) the same reply interrogates the bottom transponder to provide the total ranges from the ship to the submersible to each transponder and back to the ship. The range data is processed to determine the positions of both the ship and the submersible relative to

the bottom transponders. The resulting track information is displayed on the x-y plotter and printed out by the teletype.

There are five standard transponders available for use in the ATNAV system; three are releaseable and two are not. The recommended interrogate/respond frequencies of the submersible transponder is 11 kHz and 9 kHz, respectively. The bottom-mounted transponders will respond to the 9 kHz on one of 13 selectable frequencies ranging from 9 through 15 kHz at increments of 500 Hz. The range of frequencies, when using three or more transponders concurrently, must stay within a 4 kHz band in order to be compatible with the standard shipboard Ranging Receiver. The standard transponder battery life is one or two years, or 100,000 interrogations. The depth of transponder operation is 3,000 feet (914m) or 20,000 feet (6,096m).

There are several other navigation systems offered by AMF for submersibles:

ATNAV II - An updated ATNAV system offering larger area coverage (16 transponders), data recording, dead reckoning capability, and more rapid program loading.

SUBATNAV - The Submersible Acoustic Transponder Navigation System or SUBATNAV is a navigation system built specifically for use on small submersibles with a small payload. The submersible components consist of a 3-channel ranging receiver, a microprocessor and a control/display unit. The system navigates by determining the slant range to three bottom-mounted transponders and uses this information to compute the submersible's position which is shown on the display unit in x-y coordinates relative to the transponder field. The SUBATNAV system also provides a navigation mode for traveling from point-to-point (transponder-to-transponder). By selecting a particular point, the display unit shows the

distance offtrack left or right of a straight line to that point. Options such as CRT display and data storage are available.

5.5.2 The ELA System

This corporation is located in Montrouge, France and recently obtained U.S. representation through Inspectronic Corp., City Island, New York. The navigation system's (series 20) underwater components consist of three bottom-mounted and one submersible-mounted transponder; the surface craft components consist of an acoustic Ranger (PA21) with two interrogation channels, a computer and interfacing electronics. (A display unit, x-y plotter and data recorder are optional.) The deployment, net calibration, navigation procedures and mathematics are, to all intents, similar to that described for the ATNAV system.

The ELA system can also be used by a surface craft to determine the submersible's position, or it may be used by the submersible alone. When used by the submersible only, a position accuracy (relative to three transponders) of $\pm$1 meter (3.2 ft) is obtainable. When the surface ship uses the system to obtain the submersible's position, a variety of factors, e.g., celerity and the ship's own movements introduce inaccuracies. The manufacturers state that, if the surface ship is moving (drifting) at less than 1 knot (1.8 km/hr), the position error will be in the order of $\pm$5 meters (16.4 ft).

The Ranging components (which can be used on the surface or in the submersible) consist of a unit for computing and displaying up to four distances (PA21), a transducer for interrogating/receiving the transponders and a connecting cable with provisions for a thru-hull fitting at its mid-point. The unit transmits on 16 kHz and can receive from 8.5 to 15 kHz at 500 Hz steps. The outboard

transducer can withstand a pressure of 200 atmospheres or approximately 6,600 feet (2,012m) of sea water. The weight in water of the transducer is 22 lbs (10kg) and the weight in air of the compute/display unit is 30 lbs (13kg). The transponders (Model AT21) are omnidirectional and can be interrogated on 9, 11 or 16 kHz and will respond from 8 to 15 kHz selectable at 500 Hz steps. The standard battery pack provides a life of two months (on standby) or 100,000 responses. The maximum depth capability of the transponders is 600 meters (1,969 ft).

Several options are available in the basic ELA System:

1. Navigation Display (PA22): displays the position of a moving craft with respect to four transponders on a CRT;
2. Data Recorder (PA23): data recorder with a digital clock and display, an eight-digit printer and a digital cassette recorder;
3. Cassette Reader (PA24): used in conjunction with a computer (Hewlett-Packard HP 21, 12 or comparable) and an x-y plotter for processing of results.

5.5.3 The Mesotech System

This system is also transponder-based and is marketed by Mesotech, Ltd., No. Vancouver, B.C. It consists of from 4 to 16 bottom-mounted transponders, two transmit/receive transducers, one receiver and one interrogator. A minimum of four transponders are required; these are installed by the support ship and their positions located to within 1 km (0.5 nm). Sixteen frequencies from 7 kHz to 16 kHz are used by the transponders. The remaining two frequencies are used by the interrogator and transducers to: 1) initiate transponder reply, or 2) initiate a transponder into a 64 pulse pinger mode, or 3) to selectively operate the acoustic release on the transponders. The interrogator

and receiver will either display the four closest or four selected transponders. The interrogator can be computer-controlled to interrogate at any rate with intervals of between 5 and 60 seconds, or automatically in five second steps between 5 to 30 seconds or it can be triggered manually. To correct for sea water sound velocity variations, temperature and conductivity sensor information is fed into the computer, as is depth of the vehicle from an onboard quartz pressure transducer.

All data in the Mesotech system is stored on discs and displayed on a teleprinter. A left-right track indicator box provides the submersible pilot with course corrections to initially enter the transponder array or proceed to a chosen location, or to steer a selected track. The system provides a relative final accuracy of $\pm$30m (98 ft), when correlated with a surface electronic aid to navigation (e.g., DECCA, SATNAV); overall geographic accuracy of 50 to 200m (164 to 656 ft) is attainable. The goal of the system is to provide a submersible's relative position accuracy to within $\pm$3m (10 ft) and $\pm$0.3m (1 ft) depth.

During the FAMOUS project's submersible operations in the summer of 1974, a three-transponder network, similar in operating concept to both ATNAV and ELA, was used to track the vehicles at depths between 2,500 meters (8,202 ft) and 3,000 meters (9,842 ft). The sea bottom in this area of the Mid-Atlantic Ridge is quite rough. This bottom roughness resulted in interference with the interrogate signals (1 or 2, rather than 3 transponders responding). However, Jarry and Farcy (See Navigation in Section 6.0) report that a relative accuracy of 10 meters (33 ft) was obtained within the three-transponder net which covered an area of 20 square kilometers (5.8 nm^2). Smith and others (See Navigation in Section 6.0) have developed, through mathematical analysis,

guidelines for survey design in deep ocean transponder navigation and show that the position accuracy can be severely affected by the geometry of the survey points and that the optimal survey pattern will change with depth of water relative to the dimensions of the survey net.

5.5.4 Doppler Navigation

The Harbor Branch Foundation submersibles and the U.S. Navy's DSRVs employ a form of Doppler navigation. The characteristics of the JOHNSON-SEA-LINK's Sperry SRD-101 Doppler Navigation System will be described as it is representative of the state-of-the-art.

The SRD-101 system consists of the following major components: outboard is a transducer assembly and an electronics pressure can; inboard components are a control and indication unit mounted in the pilot's sphere, and a magnesyn compass mounted on the forward part of the inner ring for the sphere hatch.

The SRD-101 employs beams of continuous wave ultrasonic energy, directed obliquely at the bottom, to obtain true speed over the bottom in the fore-aft and starboard-port directions. The difference in frequency between the received fore and aft signals and between the received starboard and port signals is converted by analog computer circuits to drift angle, speed, and distance information. Speed and distance are displayed on separate instruments. Drift angle information is displayed on a heading-drift indicator, along with desired magnetic course and actual magnetic heading. The display is arranged in such a way that the desired magnetic course is made good by a simple pointer matching procedure.

The SRD-101 system is operational to 2,000 feet (610m) depth and works within the range of 4 feet (1.2m) to 250 feet (76m) altitude off the bottom. It transmits on 400 kHz, requires 24 to 31 VDC current (1.5 amps) and provides the following data: speed ±2 percent of full scale up to 10 knots (18 km/hr); distance ±1 percent of that traveled; drift angle ±1 degree (root mean square). Heading information is also provided, but its accuracy is contingent upon the accuracy provided by, in JOHNSON-SEA-LINK's case, a magnesyn compass.

5.5.5 Tracking

There are a variety of techniques employed to track a submersible from a surface craft; these are tabulated and discussed by Busby (See "General" in Section 6.0). The only known commercial variation from historical tracking techniques is through the application of the AMF Acoustic Beacon. The self-powered AMF Beacon contains a precision quartz clock which may be synchronized before deployment with a clock in the surface support craft's Ranging or Range Bearing Receiver. At precisely timed intervals, the Beacon clock activates acoustic pulses; the pulses arrive at the shipboard Receiver delayed by a time that is directly proportional to the distance between the Beacon and the Receiver; consequently, slant range to the submersible may be obtained. The Range Bearing Receiver provides similar slant range measurements and, by use of a hydrophone array that measures the phase difference of the arriving wave front, the bearing (relative to the surface craft) may also be obtained.

There are two AMF Acoustic Beacons: a 3,000 ft (914m) model and a 20,000 ft (6,096m) model (Mod. 365 and 360, respectively). A releaseable Beacon (Mod 362) is also available for depths to 20,000 feet. The transmitting pulse frequency is from 9 to 15 kHz; the beam pattern is omnidirectional; the pulse

repetition rate is selectable from 10 to 100 seconds at 10 second increments and the battery life is six weeks. The clocks' general characteristics are:

Frequency	5 mHz
Settability	$\pm$5 parts in 10^{10}
Drift with Aging	3 x 10^9/24 hrs after 72 hrs
	1 x 10^9/24 hrs after 30 days

Drift with temperature is less than 5 parts in 10^9 from -2 degrees C to 25 degrees C (28.4 degrees F to 77 degrees F).

Accuracies of the slant range measurement or of the bearing measurements are not stated by AMF nor by their users.

5.6 Life Support

Life support characteristics and components, vehicle-by-vehicle, are contained in Table 5.4. The following narrative summarizes these data and discusses various new or unique approaches.

5.6.1 Duration

Life support duration, the capability for supplying oxygen and removing carbon dioxide, has increased since the advent of the PISCES III incident. Prior to the summer of 1973, somewhat less than 72 hours/occupant (or 216 man-hours in a 3-man vehicle) was about average for the field at large. Now, 72 hours/occupant is minimal for North Sea operators and 112 hours (or 4.6 days/occupant) is average. The overall average of life support duration for the vehicles listed in Table 5.4 is 85 hours/occupant or 3.5 days. The minimal amount is

TABLE 5.4 SUBMERSIBLE LIFE SUPPORT COMPONENTS

	MAN-HRS DURATION	CO_2 SCRUB. COMPOUND	MONITORS: O_2	CO_2	H	TEMP.	HUMID.	PRES.	TRACE CONT.	AIR COND.	FOOD WATER	EMERG. CLOTH.	FIRST AID KIT
ALVIN	216	LiOH	X[1]	X	O[2]	X	X	X	0	0	X	0	X
AQUARIUS I	336	LiOH	X	X	0	X	X	X	0	0	X	X	X
ARGUS	216	CaOH	X	X	0	X	X	X	0	0	X	0	X
AUGUSTE PICCARD	2,136	LiOH	X	X	X	X	X	X	CO, KO_2 freon	0	X	X	X
BURKHOLDER I	96	Soda sorb	X	X	0	X	0	X	0	0	X	0	X
CYANA	216	Soda sorb	X	X	0	X	X	X	0	Silica gel	X	0	0
DEEP QUEST	204	LiOH	X	X	0	X	X	0	X	Heaters	X	0	X
DIAPHUS	180	LiOH	X	X	0	0	0	X	0	0	Wat. only	0	X
DOWB	270	LiOH	X	X	0	NA	NA	NA	CO	0	NA	0	NA
DEEPSTAR-2000	144	LiOH	X	X	0	X	X	X	NA	NA	X	NA	X
DEEPSTAR-4000	288	Soda lime	X	X	0	X	X	X	0	0	X	0	NA
DSRV I & II	384	LiOH	X	X	0	X	X	X	0	0	Wat. only	0	X
GRIFFON	120	Soda lime	X	X	0	X	X	X	0	0	Wat. only	0	X
HAKUYO	156	Baralyme	X	X	0	X	0	0	0	0	0	0	0
JOHNSON-SEA-LINK I & II	480	Soda sorb, LiOH	X	X	0	X	0	X	freon	X	X	X	X
LEO	340	LiOH	X	X	0	X	X	X	0	0	X	0	X
MERMAID II	240	LiOH	X	X	X	X	X	X	0	0	X	0	X
MERMAID III & IV	160	Drager-Atemkalk	X	X	0	0	0	0	0	0	NA	NA	NA
MOANA I	288	Soda lime	X	X	0	X	X	X	0	Heaters	X	0	0
MOANA III, IV, V	288	Soda lime	X	X	0	X	X	X	0	Heaters	X	0	0
NEKTON A, B, C	144	Soda sorb	X	0	0	0	0	X	0	0	X	X	0
NEMO	270	Baralyme	X	X	0	X	0	X	0	Silica gel	X	0	0
PC8B	240	Soda sorb, LiOH	X	X	0	X	0	X	0	0	X	0	0
PC-9	250	Soda sorb, LiOH	X	X	0	X	X	X	0	0	X	0	0
PC-1201	240	Soda sorb, LiOH	X	X	0	X	0	X	0	0	X	0	0
PC-1202	360	Soda sorb, LiOH	X	X	0	X	0	X	0	0	X	0	0
PC-1203	160	LiOH	X	X	0	X	X	0	0	0	X	0	0
PC-14C-2	180	Baralyme, LiOH	X	X	0	X	0	X	0	0	0	0	0

TABLE 5.4 SUBMERSIBLE LIFE SUPPORT COMPONENTS (Cont.)

	MAN-HRS DURATION	CO_2 SCRUB. COMPOUND	MONITORS							AIR COND.	FOOD/ WATER	EMERG. CLOTH.	FIRST AID KIT
			O_2	CO_2	H	TEMP.	HUMID.	PRES.	TRACE CONT.				
PC-16	240	LiOH	X	X	0	X	X	X	0	0	NA	NA	NA
PISCES II	352	LiOH	0	X	0	X	X	X	CO	0	X	X	X
PISCES III	352	LiOH	X	X	0	X	X	X	0	0	X	X	X
PISCES IV	180	Drager sorb, LiOH	X	X	0	0	0	X	0	0	X	X	X
PISCES V	168	LiOH	X	X	0	X	X	X	0	0	X	X	0
PISCES VI	216	LiOH	X	X	0	X	X	X	0	0	X	0	X
PISCES VII & XI	216	CaOH	X	X	0	X	X	X	0	0	X	0	X
PISCES VIII & X	336	LiOH	X	X	0	X	X	X	0	0	X	0	X
PRV-2	123.5	Soda sorb, LiOH	X	X	0	0	0	X	0	0	0	0	X
PS-2	288	LiOH	X	X	0	X	X	X	0	0	X	X	X
SDL-1	204	Drager sorb	X	X	0	X	0	X	0	0	X	X	X
SEA CLIFF	111	LiOH, Baralyme	X	X	0	X	X	X	0	0	0	0	0
SEA EXPLORER	48	Soda sorb	0	0	0	0	0	X	0	0	0	0	0
SEA OTTER	200	LiOH	0	X	0	0	0	X	0	0	X	0	X
SEA RANGER	240	Baralyme	X	0	0	X	0	X	0	0	0	0	0
SHELF DIVER	216	Soda lime	X	X	0	0	0	X	0	0	X	0	X
SHINKAI	192	LiOH	X	X	0	X	X	X	0	Dehumid-ifier	X	0	0
SKADOC 1000	144	Soda sorb	X	X	0	X	X	X	0	0	0	0	X
SNOOPER	48	Baralyme	X	0	0	0	0	0	0	0	0	0	0
TAURUS	500	LiOH, Soda sorb	X	X	0	X	X	X	0	0	NA	NA	NA
TRIESTE II	139.5	LiOH	X	X	0	X	X	X	0	X	Water only	0	0
TURTLE	111	LiOH, Baralyme	X	X	0	X	X	X	0	0	0	0	0
URF	980	Soda lime	X	0	0	X	0	X	0	Heaters, Silica gel	X	0	NA
VOL-L1	840	LiOH	X	X	0	X	X	X	CO	0	X	0	X

1. X = On board
2. 0 = Not on board

found in the DSRVs with 13.7 hours/occupant (4 crew and 24 rescuees); the maximum is AUGUSTE PICCARD where 305 hours/occupant (12.7 days) is provided.

5.6.2 CO_2 Scrubbing Compound

In decreasing order or occurrence, the following compounds are used in submersibles to remove or scrub CO_2 from the cabin atmosphere: LiOH (34%), soda sorb and LiOH (14%), soda lime (14%), soda sorb (13%), Baralyme (8%), Drager Sorb (5%), CaOH (5%), LiOH and Baralyme (5%), Drager Sorb and LiOH (2%).

The use of combinations of scrubbing compounds, such as LiOH and soda sorb, is for the sake of economy. Soda sorb, which is less expensive than LiOH, is used for routine operations. The LiOH, which retains more of its absorbing capability at temperatures below 40 degrees F (4 degrees C) is carried for emergency use only.

Experiments on the capacity of LiOH to absorb CC_2 under repeated compression/decompression cycles were conducted at the Harbor Branch Foundation by T.C. Wang (See Life Support, Section 6). After 25 cycles to a pressure equivalent to 150 feet (46m) of sea water, analyses of the test LiOH samples showed a loss of about 1.5 percent CO_2 absorbing capacity after each cycle, and a total reduction in absorption efficiency of 30 percent after the full 25 cycles. For samples after 25 cycles, the CO_2 absorption capacity at room temperature was found to be only 6 percent more effective than at 38-40 degrees F.

In July of 1975, the Canadian Department of Environment began conducting comparison tests between the absorbing qualities of LiOH and Drager Sorb. The preliminary results indicate that the Drager Sorb compound is almost equal to LiOH absorbing capacity at 1 degree C (34 degrees F) and 15 degrees C

(59 degrees F), but not as efficient at 5 degrees C (41 degrees F) and 10 degrees C (50 degrees F). The results were not considered definitive and further tests were scheduled.

5.6.3 Atmospheric Monitors

Devices to measure O_2, CO_2, H, temperature, humidity, pressure, CO, KO_2 and freon can be found aboard today's submersibles. Only one vehicle (AUGUSTE PICCARD) measures all these atmospheric components; a breakdown of the percentage of submersibles which measure a particular property is shown by the following list:

Property	% of Vehicles Which Measure
Oxygen	95
Carbon Dioxide	89
Temperature	81
Humidity	61
Pressure (internal)	90
Hydrogen	3
Carbon Monoxide	6
Potassium Dioxide	1.5
Freon	3

There is no consistency from vehicle-to-vehicle in the type of device used to measure a particular property. Similarly, there is no consistency in the frequency of the measurement. In almost equal distribution, various atmosphere components are monitored once every 30 minutes, once every 20 minutes, once every 15 minutes, or, finally, at a time which is convenient for the pilot.

A number of vehicles have instruments which continuously measure and display O_2 and CO_2 percent or partial pressure, and in these instances the pilot visually checks the display from time-to-time. Others require that the pilot stop whatever he is doing to measure these properties with a hand-held device. Temperature, humidity and pressure are all monitored by a conventional device which merely requires a visual check. The reasons for measuring temperature and humidity are not evident, because most operators do not maintain a log or record of the measurement and have no means of controlling either property if it became intolerable while submerged. Pressure measurements, in non-lockout submersibles, are generally made to infer the partial pressure of O_2 in the cabin atmosphere; if the pressure has decreased, it is taken as an indication that O_2 has decreased and the pilot (if he has the means) checks the O_2 concentration with a measuring device or simply adds O_2 until the cabin pressure increases to a pre-selected standard.

A small number of vehicles have an automatic alarm that actuates when O_2 or CO_2 content goes above or below a specific range. These alarms are both visual (a red light) or audible (a buzzer).

The measurements of contaminants, such as CO, KO_2 and freon, is performed only in those instances where their concentrations to toxic levels is possible. Normally, the short 6 to 8 hour dive duration of virtually all submersibles does not result in contaminant levels even approaching a toxic concentration. The operators of DEEP QUEST routinely measured trace contaminant concentrations on all of their early dives; finally, when no change in concentration was found dive-after-dive, the practice was discontinued.

5.6.4 Air Conditioning

Twelve submersibles have some means to control either temperature or humidity or both. Two submersibles carry silica gel in the cabin to reduce humidity; one carries an electrical dehumidifier. Five submersibles have electric heaters for cold water operations. The Harbor Branch Foundation vehicles and TRIESTE II have an air conditioning system to reduce the temperature in the pilot's sphere. The Swedish URF carries both electric heaters and silica gel. The general absence in air conditioning/control devices is attributed to the philosophy that the occupants can tolerate extremes in temperature and humidity because the dive will be short, and the desireability of conserving electrical power for instruments directly related to mission tasks overrides occupant comfort.

5.6.5 Emergency Food/Water

Eighty five percent of present submersibles carry either food or water or both for emergency use.

The amounts of potable water carried in each vehicle varies from 1 2/3 pints (0.7 l.) to 14 pints (6.6 l.) per occupant. The majority of vehicles carry from three to eight pints (1.4 to 3.8 l.) per occupant. A number of the operators consider that the quantity of water (and food) carried to provide life support is equal in duration to that supplied by the O_2/CO_2 system. According to the Marine Technology Society, a "Standard Man" will require six pounds (2.7kg) of water per day, or approximately six pints (2.8 l.); if this value is used, then no submersible carries water adequate for more than two days. Even if the value is halved, only four days supply of potable water is obtained. This does not necessarily mean the operator's assumptions are incorrect, but no explanation is readily available to substantiate the calculations.

A few vehicles carry potable water in sealed tins; most carry it in containers which are emptied and refilled between dives. TRIESTE II does not carry drinking water per se, but the water derived from the dehumidifier/cooler is considered potable. The JOHNSON-SEA-LINK vehicles also carry desalination kits by which sea water (brought in through the lockout hatch and the pilot's sphere) may be converted to potable water.

Food supplies also vary from vehicle-to-vehicle, both in quantity and amount. Most operators feel that the amount carried is also equal in sustenance to the life support (O_2/CO_2 system) duration. A large number of operators feel that food is not an important consideration, in that, the occupants can survive without food for the entire limit of life support (e.g., 3 to 5 days).

The type of food carried for emergencies is: C-rations, life boat-type rations, space rations, dehydrated foods, food blocks, candy, mixed (raisins, Hershey bars, nuts, dextrose, ship's biscuit) and, in one instance, rice and dried fish.

5.6.6 Emergency Clothing

The term emergency clothing refers to items of wearing apparel which are carried in the submersible to provide warmth; it also includes other items such as, sleeping bags and "space" blankets.

Approximately 23 percent of all submersibles carry some form of emergency clothing. This percentage does not include lockout submersibles where wet suits may or may not be carried for a particular mission. This value does include vehicles under construction or undergoing modifications where the operator was not certain of the nature of the protection, but planned to include some form thereof.

The nature of thermal protection varies between submersibles as the following tabulation reveals:

AQUARIUS I - U-Vic Thermofloat jackets

NEKTON - Exposure suit (carried during cold water operations)

PISCES II & III - Two pair wool socks, two sweaters, two thermal blankets

PISCES IV - "Space" blankets

PS-2 - Sweaters and caps

SDL-1 - Sleeping bags; super mylar "Space Suits"

The majority of the above items are either conventional items or products of the space age which combine light weight with excellent thermal insulation.

The U-Vic Thermofloat jacket is a fairly recent (1975) product developed from five years of research at the University of Victoria, British Columbia, and produced and marketed by Mustang Sportswear Ltd, Vancouver, B.C. The jacket is designed to reduce heat loss at critical body areas, such as the sides of the chest and the groin, while providing 15.5 lbs (7.1kg) of surface buoyancy in a face-up position. It can be worn as a windbreaker for normal use and quickly converts to a short "wet suit" for in-water use. The research and designing of the U-Vic Jacket is described by Collins (See Life Support in Section 6.0).

5.6.8 Medical Supplies

Fifty eight percent of all submersibles carry medical supplies, these consist of the standard contents of small first aid kits. The only variation to this procedure is in PS-2 where, in addition to the first aid kit, anti-burn cream and methedryne pills are also carried.

6.0 PUBLICATIONS

6.1 MANNED SUBMERSIBLES

6.1.1 Activities

Freeland, G.L. and Swift, D.J.P. 1975 New York alternative dumpsite assessment reconnaissance study of surficial sediments. Proc. 7th Ann. Offshore Tech. Conf., V.III, p. 505-511

Describes the use of NEKTON in two geological and three biological dives in the New York Bight.

Heirtzler, J.R. and Bryan, W.B. 1975 The floor of the Mid-Atlantic Rift. Scientific American, V. 232, n.2, p. 79-90

Presents the initial results of ALVIN, CYANA and ARCHIMEDE's participation in Project FAMOUS. Describes data acquisition instruments and navigational techniques.

Ishikura, H. 1975 The submersible program in Japan. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75 p. V-28 through V-38

An overview of Japanese diving activities and details of operating submersibles.

Johnson, W.E., Howland, J.H. and Doyle, R.J. 1976 Deep submergence: The U.S. Navy's operating forces. Proc. 1976 Offshore Tech. Conf., V.11, p. 505-516

Characteristics and operational summaries of TRIESTE II, SEA CLIFF, TURTLE and DSRV 1 & 2 are discussed. Several material and reliability problem areas brought to light during these operations are presented; these are compensating fluids, cables/connectors, corrosion, batteries, buoyancy materials and launch/retrieval.

MacDonald, M.D. 1975 The submersible program in Canada. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. V-4 through V-22

A fairly comprehensive review of submersible activities in Canada which centers around vehicles built by International Hydrodynamics. Includes description of life support procedures, training and emergency devices.

MacInnis, J. 1975 Diversubs, an overview. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. IV-1 through IV-9

A review of the concepts that lead to the development of lockout submersibles. Includes a brief treatment of lockout vehicle history and their future.

Mulcahy, M. 1976 Manned Submersibles - Workboats show explosive growth. Sea Technology, V.17, n.1, p. 34-36

A discussion of the international submersible field at large outlining its explosive growth and comparing representative vehicles produced by five participants.

Pass, H. 1975 The submersible program in the United Kingdom. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. V-1 through V-3

A brief summary of Vickers Oceanics submersibles and operations.

Rickert, W.W. 1974 Reasons for small observation submersibles and 1974 pipeline inspection operations using NEKTON. Proc. 5th Ann. International Diving Symposium. Assn. Diving Contractors and Mar. Tech. Soc., p. 1-15

Describes the tasks and operating procedures for pipeline inspections in the Gulf of Mexico by the NEKTON series submersibles.

6.1.2 Applications

Chapman, R.R. 1976 Sub sea surveys. Proc. 1976 Offshore Tech. Conf., V.III, p. 465-477

Compares surface-oriented and towed sensor site and route survey techniques against manned submersibles. Concludes, by analysis, that the submersible overcomes many of the limitations inherent in surface surveying by providing greater accuracy in details and in situ positioning. Outlines improvements needed to optimize submersible surveying potential.

Hitchings, G.A. and Labiosa, T.D. 1976 The planning and execution of offshore site investigations for a North Sea gravity platform. Proc. 1976 Offshore Tech. Conf., V.1, p. 63-74

Describes the role of a manned submersible in a site survey in the North Sea. Navigation systems and data collection systems (echo sounder, television, side scan sonar, pressure/depth) are described and the results of the submersibles' work are discussed. Cost figures are presented.

Holland, R.H. 1976 Applications for diver lockout submersibles. Proc. 1976 Offshore Tech. Conf., V.III, P. 1031-1035

Describes recent industrial applications of diver lockout submersibles in the North Sea. Identifies tasks which the lockout submersibles perform more efficiently than other means and compares the lockout vehicle with other work systems.

6.1.3 Classification/Safety

Pass, H. 1975 The sinking and rescue of PISCES III. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. II-11 through II-17

Relates the events leading up to the sinking of PISCES III and the subsequent steps taken to affect rescue.

Talkington, H.R. 1975 Self-help rescue capability for submersibles. Mar. Tech. Soc. Jour., V.9, n.4, p. 20-29

Target enhancement features and new equipment for use in undersea emergency rescue are defined and discussed. The features are aimed at minimizing risk and maximizing the submersible's location on the surface.

Tangen, H.D. and Evenson, G. 1976 Safety aspects and classification of deep diving systems. Proc. 1976 Offshore Tech. Conf., V.II, p. 517-528

Presents the development and the application of Det norske Veritas' Rules for the Construction and Classification of Diving Systems.

Youngblood, D. 1975 The JOHNSON-SEA-LINK incident. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. II-18 through II-28

Relates the events leading up to the entanglement of J-S-L I and subsequent rescue efforts. Discusses the major lessons learned from this incident and the steps taken by Harbor Branch Foundation to avoid and react to such incidents in the future.

6.1.4 Design

Anonymous 1976 ARMS extends man's capacity. Offshore, V.36, n.5, p. 285-288

Describes the current development of ARMS (Atmospheric Roving Manipulator System), a one-atmosphere, 3,000 ft. (914m) manned and tethered diving bell equipped with an advanced manipulator system for performing observation and work tasks on blowout preventers and ancillary subsea equipment.

Atwood, D. and McCann, C. 1975 Human-engineering evaluation of the SDL-1. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. III-9 through III-19

Discusses the results of a human engineering evaluation of the SDL-1 and presents improvements in design and layout of operator seating and in controls and displays associated with some aspects of vehicle operation .

Cantwell, J. 1975 Computer mission simulation for parametric design of undersea vehicles. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 860-869

Describes a mathematical model developed to assist in design of submersibles (manned & unmanned) and their major subsystems, including sensors, propulsion units, energy package and structures.

Fike, J.W. and Dolan, R.P. 1976 A submersible diving system for science. Proc. 1976 Offshore Tech. Conf., V.II, p. 529-538

A detailed description of JOHNSON-SEA-LINK II

Shumaker, L. 1975 Limitations of small submersibles. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. I-12 through I-17

A general discussion regarding aspects of submersible design, equipment and operations.

Stachiw, J.D. 1975 Safer submersible viewports. Ocean Ind., V.10, n.3, p. 51-53

Presents the results of a study at the Naval Undersea Center, San Diego in which the impact resistance of plastic spherical shell viewports was investigated. Two objectives were sought: 1) determination of impact resistance in existing types of plastic spherical shell viewports; 2) development of collision guards for such viewports that offer minimal impairment to observers field of vision.

6.1.5 General

Chapman, R. 1975 No Time On Our Side. Grays Publications Ltd., London

A personal account by one of the survivors of the PISCES III incident in August-September 1973.

Busby, R.F. 1976 Manned Submersibles. U.S. Government Printing Office Publication 102, 745 p.

A semi-technical account of the history, design, development and operation of manned submersibles from 1934 through to the present.

6.1.6 Insurance

Dawson, J. 1975 Insurance thinks deep. Mar. Tech. Soc. Jour., V.9, n.6, p. 29-30

Brief discussion of insurance considerations for undersea hardware.

6.1.7 Life Support

Collis, M.L. 1975 Cold water survival techniques advanced by Canadian researchers. Ocn. Ind., V.10, n.8, p. 46-49

A detailed, five-year study of the physiological responses of the human body to long-term immersion was performed at the University of Victoria, B.C. Results include: 1) new curves for survival time vs. water temperature; 2) design and manufacture of a cold water survival/flotation jacket which can be worn in everyday use, and 3) recommended flotation positions to conserve body heat in cold water.

Greene, K. 1975 Navy DEEP SUBMERGENCE RESCUE VEHICLE. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, P. IV-12 through IV-21

A brief description of the DSRV's characteristics is presented. Life support requirements and medical considerations are discussed in fair detail.

Parker, F. 1975 Life support systems. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. I-18 through I-32

Discusses and describes O_2 and CO_2 supply and removal systems, respectively, in submersibles. Difficult to follow at times, but worth the effort.

Wang, T.C. 1975 Decompression cycling effects on the shelf life of lithium hydroxide. Mar. Tech. Soc. Jour., V.9, n.4, p. 36-40

Lithium hydroxide samples were cycled 25 times to depths (pressure) equivalent to 150 feet under simulated diver lock-out chamber conditions. Two sets of cycle temperatures were held: 70-73 degrees F and 38-41 degrees F at 85-90% RH. The results show about 1.5% of CO_2 absorption capacity was lost on each compression-decompression cycle. At the end of 25 cycles the efficiency was reduced to 70% (70-73 degrees F) and 72.7% (38-41 degrees F) of its initial reactive efficiency.

6.1.8 Navigation

Hosum, D.S. and Donnelly, J.D. 1975 ALVIN Gyrocompass Performance Report. WHOI Tech. Memo, WHOI-4-75, 22 p.

Describes the performance of two gyrocompasses, a Gyrosystem, Inc. Mod. 800 and a Sperry Marine Systems Subminiature Gyrocompass, aboard ALVIN between 5 June and 15 Sept. 1976 during a series of deep and frequent applications.

Jarry, J.J. and Farcy, A.J. 1975 Navigation system used by submersibles in FAMOUS project. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 882-886

A bottom-mounted, three-transponder, navigation system is described which was used by submersibles and surface ships to conduct oceanographic surveys/research during Project FAMOUS. The transponder system provided coverage of a 20 km^2 area and a submersible position accuracy of $\pm$ 10m.

Smith, W., Marquet, W.M. and Hunt, M.M. 1975 Navigation transponder survey: design and analysis. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 563-567

A technical analysis of the standard, three transponder geometry is performed. Results show that the accuracy of the least squares estimation procedure is very sensitive to the survey geometry and that careful design of the survey pattern can increase the survey accuracy by a factor of five to ten.

Stockton, T.R. and McLennan, M.W. 1975 Acoustic position measurement, an overview. Proc. Offshore Tech. Conf., V.1, p. 255-264

The basic concept of acoustic position measurement is discussed, generalized equations are developed and the effect upon the equations of simplified array patterns and simplifying approximations is examined. Inaccuracies imposed by each error source are discussed, and position error contour curves for typical measurement geometries are presented.

6.1.9 Personnel

Biersner, R. 1975 Personnel selection, medical qualifications and training requirements. Medical Aspects of Small Submersible Operations. Undersea Med. Soc., Rept. No. WS: 7-1-75, p. III-1 through III-8

Presents the current U.S. Navy approach to selection and training for deep submergence vehicle personnel

6.1.10 Power

Hosom, D.S. 1975 Oil filled Electric Cables External to the Pressure Hull on DSRV ALVIN. WHOI Tech. Memo. WHOI-7-75, 21 p.

Provides background information on undersea cables of conventional construction and of the oil filled type. Design considerations for oil filled cable systems are presented as well as description of the ALVIN oil compensated electrical system. Descriptions of individual components used in the ALVIN system are provided as well as operating experience. This information is of use in designing oil filled electrical cables external to the pressure hull of any submersible.

Hosom, D.S., Donnelly and Page, W. 1975 ALVIN Battery Charging Procedures. WHOI Tech. Memo. WHOI-3-75, 20 p.

Describes procedures followed for initial activation and routine maintenance of ALVIN's pressure-compensated, lead acid batteries.

Lockheed Palo Alto Research Laboratory 1975 Lithium-Seawater Power System. Final Technical Report 20 May 1975. LMSC-D454434, ARRA Order Nr. 2892, Prog. Code Nr. 5E20, 25 p. (Distribution limited to U.S. Gov. agencies only; requests must be referred to Commander, U.S. Army Missile Command, Attn: AMSMI-RNS, Redstone Arsenal, AL35809

Describes the results of work conducted on a lithium-seawater power system in which the basic objective was to compare the capabilities of the lithium-seawater system to the diesel electric system when providing propulsion power to submarines. A secondary objective was to determine if a portion of the submarine onboard batteries could be replaced with the lithium-seawater system.

McCartney, J.F. 1975 Expendable Power Sources for Undersea Applications. Tech. Note 1391, Civil Engineering Lab., Port Hueneme, Ca., 97 p. (Distribution limited to U.S. Government agencies only)

Presents a review of power requirements for present and projected Navy missions. State-of-the-art and advanced power sources and power systems are surveyed and tabulated. The performance of these systems is compared with the mission requirements to determine selected candidates for more detailed investigation.

Newman, J.P. and Miller, H.A. 1975 Electrical design considerations in modern commercial submersibles. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 877-881

Describes key areas of currently designed electrical systems for contemporary commercial submersibles, concentrating on Perry Ocean Engineering products. Includes electrical distribution, main power, emergency power, propulsion, navigation, communication and instrumentation.

Wilson, J.V. 1976 Underwater mateable electro-mechanical connectors for power and signal cables. Proc. 1976 Offshore Tech. Conf., V.11, p. 589-599

Describes the design and testing undertaken by the U.S. Navy's Civil Engineering Laboratory to develop a "wet" connector designed for underwater interconnection of rigid structures, cable structures and for connection to submersible vehicle batteries.

6.1.11 Search

Potter, M.C. 1975 Meaning in visual search. Science, V.187, p. 965-966

A series of tests were given to students at MIT to answer two questions: 1) can an observer detect an expected scene even when it is presented so briefly that it would not otherwise be remembered; 2) if so, what sort of advance information is required for the observer to spot it? Results: Knowing the exact appearance of a target (a photograph) was little better than knowing only its general meaning (e.g., a boat, two men drinking beer, a child and a butterfly). The results are applicable to undersea search and inspection tasks.

6.1.12 Support Craft/Devices

Dolan, R.B. 1976 Aluminum hydrocrane for submersible operations. Proc. 1976 Offshore Tech. Conf., V.II, p. 551

Discusses the philosophy of design, the construction, testing and operation of the articulated crane launch/retrieval system used for JOHNSON-SEA-LINK I & II.

Lachmann, B. 1975 Submarine support vessel (SSV). Proc. 7th Ann. Offshore Tech. Conf., V.III, p. 613-620

A design study by Kockums Mekaniska Verkstads AB which shows the feasibility of a submarine to support submersibles. Discusses the advantages, operations, characteristics and cost of such a vessel to support a 50 ton sub.

No. of Series	US $
1	30 million
2	25 million
5	22 million

Also contains diver lockout facilities.

Lachmann, B. 1975 Submarine support vessel. Proc. Offshore Tech. Conf., V.III, p. 613-620

Presents the design and brief operational requirements of a submarine in the role of a submersible support platform.

6.1.13 Weight and Balance

Sharp, A.G. 1975 DSRV ALVIN Weight Report. WHOI Tech. Memo. WHOI-5-75, 23 p. with appendices

Weight and stability information has been updated for the research submarine ALVIN for 1975. The report includes results of the computations programmed for the Institution's XDS Sigma-7 computer, observed values resulting from the tethered trim dive and inclining experiments, and miscellaneous stability calculations. Principal results are the weight, displacement, and longitudinal and vertical components of the BG and GM distances, for the complete submersible, and for various major sub-assemblies.

6.1.14 Work Tools and Instruments

Anonymous 1976 Work systems package extends submersible work period. Ocean Ind., V.II, n.12, p. 57-58

Describes the construction, operation and applications of a Work Systems Package (WSP) developed by NUC. The WSP can be wed from a manned or unmanned vehicle and is power-independent of each. It has three manipulators (2 are for grasping; 1 for work), lights, TV cameras and tools for drilling, grinding, cutting, chipping and other manipulator tasks .

Rullman, J.D. et al 1976 Manipulator maintenance of subsea equipment - A subsystem of the submerged production system. Proc. 1976 Offshore Tech. Conf., V.II, p. 69-82.

Describes manipulator maintenance system which was designed, fabricated and tested to maintain Exxon's Submerged Production System (SPS). This maintenance system is a remotely controlled, buoyant, tethered manned submersible depth rated to 2,000 feet. It performs all SPS maintenance by replacement of modular components using special purpose manipulator tools called end effectors.

A deep water (450 feet) test is described which was performed offshore California and continuing operations are being conducted offshore Louisiana in 170 foot water depth.

Sutton, J.L., Cowen, S.J. and Thorn, J.V. 1975 Test results of an experimental holographic acoustic imaging system. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 35-38

A real time experimental holographic acoustic imaging system has been built and tested by the Naval Undersea Center to assess filled array holographic acoustic imaging systems for underwater viewing. Hardware and its performance parameters are described and listed. Qualitative results are presented and some quantitative results are discussed.

6.2 UNMANNED VEHICLES

Anonymous 1976 Remote-controlled manipulator vehicles: a new capability in offshore diving. Ocean Ind., V.II, n.4, p. 369-370

A general discussion of the advantages and applications of unmanned devices which leads into a description of Oceaneering International's RCMV and its manipulator system.

Bircham, J. and Skidmore, G. 1976 Operational use and techniques with an unmanned, cable controlled submersible in the North Sea environment. Proc. 1976 Offshore Tech. Conf., V.III, p. 1049-1056

Details of the original scientific requirements of the CONSUB vehicle as well as the vehicle's use in more commercial roles are presented. Operations from ships of opportunity both anchored and moving are described, together with solutions to some of the problems which have been experienced.

The data gathered from the operation of BAC's first unmanned submersible has proved most useful in influencing the design of new vehicles for underwater work. These new vehicles are described, and their performance and capabilities are outlined.

Estabrook, N. and Wheeler, H. 1975 Development of Deep-Ocean Work System. Proc. OCEAN 75., Mar. Tech. Soc., Wash., D.C. , p. 573-577

A Work Systems Package (WSP) has been developed by the U.S. Navy to operate at 20,000 ft. depth and conduct recovery, implantment, salvage, and repair operations. The system is modular, in that it can be adapted to both manned and unmanned vehicles. The structure, manipulators, tools, power, lighting and control are briefly described and discussed. Preliminary test results and future developments are outlined.

Fugitt, R.B. 1975 Design and operation of two remotely manned undersea vehicles. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 870-876

Presents the design philosophy and operation of two, U.S. Navy unmanned vehicles: Electric Snoopy and NAVFAC Snoopy. Evaluation tests and operational applications are briefly treated.

Jacobsen, L.R. and Jalbert, P.E. 1976 Unmanned cable controlled subsea vehicles - status and potential in the offshore oil industry. Proc. 1976 Offshore Tech. Conf., V.III, p. 1037-1048

Identifies various features of unmanned, self-propelled systems and describes their present status and capability relative to the tasks to be accomplished. Summarizes with advantages of unmanned systems over manned systems and offers recommendations toward improving the unmanned vehicle capabilities.

McCord, M. 1975 A multiplex system for a small remotely manned submersible. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C., p. 361-364

A multiplex system designed for the unmanned vehicle NAVFAC Snoopy by the Naval Undersea Center is described. The system allows simultaneous transmission of vehicle power, status (altitude, depth, heading, etc.), command (thruster controls, light switch, etc.) to be transmitted through a small diameter coaxial cable.

Noakes, J.E., et al, 1975 Surveillance system for subsea survey and mineral exploration. Proc. Offshore Tech. Conf., V.I, p. 909-914

A towed, unmanned system for underwater surveys is described. The system has been tested at sea and consists of an unmanned vehicle, called S^3, which houses an array of electronic seafloor measuring devices. S^3 is 700 lbs dry weight and can be towed at 3 to 10 kts., a terrain-following, sonar-controlled guidance system will be used for obstacle avoidance.

Scholley, G.C., Mullen, C.T. and Johnson, D. 1975 A new family of tethered underwater remote controlled work vehicles. Proc. 7th Ann. Offshore Tech. Conf., V.III, p. 667-677

Two vehicles being built: 1) under SUPSALV to aid in rescue of submersibles and salvage; 2) under AT&T contract to aid cable repair ships as inspection tools.

Skidmore, G. and Bircham, J. 1975 Development of an unmanned cable controlled submersible vehicle for surveying and sampling exposed subsea rock shelves. Proc. Offshore Tech. Conf., V.III, p. 127-138

Description of the unmanned, self-propelled CONSUB and subsequent sea trials.

Vigil, A.E., Firsbie, H.L. and Hatchett, G.L. 1975 Deep sea survey system. Proc. Offshore Tech. Conf., V.I, p. 915-922

Describes a towed, unmanned survey system which was used to conduct manganese surveys in the Pacific Ocean. Stability, control and field performance is discussed.

Wilkins, G.A., Hightower, J.D. and Rosencrantz, D.M. 1975 Lightweight cables for deep tethered vehicles. Proc. OCEAN 75, Mar. Tech. Soc., Wash., D.C. p. 138-147

Two high strength, low weight, prototype electromechanical cables have been developed by the Naval Undersea Center for use by remote controlled systems to 20,000 ft. depth. Design details for each cable are presented. Recommended actions for most effective utilization of the strength member, KEVIAR-49 are given.

APPENDIX I

NAME

CHARACTERISTICS

Length.....
Beam.....
Height.....
Draft.....
Weight (dry).....
Operating Depth.....
Collapse Depth.....
Launch Date.....

Hatch Diameter.....
Life Support Duration.....
Total Power.....
Speed: Cruise (kts/hrs).....
Max (kts/hrs).....
Crew: Pilot(s).....
Observer(s).....
Payload.....
Color.....

Pressure Hull:

Material

Shape

Dimensions (Length, Diam., Thickness)

Power Source:

Type Batteries

Battery Location

Characteristics (volts & amp-hrs)

Total Power (KWH)

Emergency Power

Maneuvering Control:

Dynamic: (Main Propulsion and Thrusters: hp, number, location)

Static: (Main Ballast tanks, variable ballast tanks, capacity and method of emptying at depth)

Trim/Pitch Control:

System Described

Degrees $\pm$ Bow Angle

Life Support:

- O_2 carried (Amount, Where, What Pressure)
- Power Required for CO_2 Scrubber
- Scrubber Compound & Amt. Carried
- Trace Contaminent Control
- Temp/Humidity Control
- Monitoring Devices:
  - O_2
  - CO_2
  - Temp.
  - Humid.
  - Pressure
- Period of Monitoring (15, 30,45 minutes...etc)

Viewing:

- No. Viewports & Location
- Dimensions of Viewports
- Television (Fixed or Trainable; inside/outside hull)

Manipulators:

- Number
- Dimensions
- Power
- Degrees-of-Freedom
- Claw Type
- Lift Capacity
- Jettisonable or not

Lift Points:

- Location
- Shape
- Dimensions (ID, Max. Opening, Thickness)
- Material
- Capacity (Tons)

External Lighting

- Units (No.)
- Where Mounted
- Watts of Power
- Type Light
- Manuf.
- Model No.

Life Jackets: (Quantity, Inflatable or Not)

Life Rafts:

- Number
- Manuf.
- Capacity

Distress Rockets:

- Number
- Type (20mm, etc.)
- Color
- Stored (Inboard/Outboard)

Distress Flares:

- Number
- Type
- Color
- Stored

Smoke Pots:

- Number
- Type
- Color
- Stored

Radar Reflector:

- Configuration
- Height Above Surface
- Where Stored

Surface Lights:

- Type
- Color
- Height Above Surface
- Power (self?)
- Duration

Anchor:

- Type
- Stored

Fire Extinguisher:

- Type
- Quantity

Emergency Food & Water:

- Duration
- Type Food
- Water Quantity
- Protective Clothing

Medical Supplies:

Automatic Deballasting (describe):

Surface Communications:

- Type
- Range
- Power Output
- Frequency of Carrier Band
- Power Required
- Emergency Power

Surface Homing Devices:

- Radio Beacon
- Frequency
- Power Source

Sonars:

- Obstacle Avoidance
  - Type
  - Manuf.
  - Frequency
  - Scan Sector (degrees)
  - Display (PPI, strip chart)
- Pingers:
  - Number
  - Frequency
  - Duration
  - Rep. Rate
  - Manuf.

Transponders

Number

Frequency

Duration

Manuf.

Directional Antennae:

Number

Manuf.

Frequency Range

Trainable?

Display

Marker Buoys (describe):

Sub-Surface Communications:

Number

Frequency(s)

Manuf.

Model

Power Source

Emergency Power

Transducer Mounted Where?

Jettisonable Components:

What?

Weight

How (elect. Mech.)

Separate Power Source Required

Location on Vehicle

Emergency Breathing:

Number

Description

Duration

Egress Procedures:

Communications Procedure: (How often check with surface craft?)

Abort Dive Due to Lack of Communications?

ABS, Lloyds etc., Classification?

SUPPORT SHIP

Name

Type Hull

LOA

Beam

Draft

Gross Tonnage

Cruise Speed

Range (miles)

Duration (days)

Crew: Ship, Sub,

Passenger Accommodations

Emergency Retrieval Capabilities

Tracking Procedure:

Instruments Used

Procedure

Log Maintained

Fix Accuracy

Surface Navigation:

Instruments Used

Anchoring Capabilities (Depth)

Communications (surface)

Type

Frequencies

Diving Upkeep & Emergency Facilities

LAUNCH/RETRIEVAL

Configuration

Location (stern, side, etc.)

Lift Capacity

Constant Tension?

Sea State Limitations

Diver Used?

Sub Status

Readiness (Operational, Inactive, Overhaul, etc.)

Owner: (Name, Address)

Operator (Name, Address)

Builder (Name, Address)

Point-of-Contact

Name

Address

phone

Cable

Telex

GLOSSARY

ABS	American Bureau of Shipping
AM	Amplitude Modulated
amp-hr	Ampere-Hour(s)
ANGUS	A Navigable General-Purpose Underwater Surveyor
ATNAV	Acoustic Transponder Navigation
AUWE	Admiralty Underwater Weapons Establishment
CB	Citizens Band
cabin	Synonymous with pressure hull
CERTSM	Centre d'etudes et de Recherches Techniques Sous-Marine
COMEX	Compagnie Maritime d'Expertises
CONSUB	Continental Shelf Submersible
CORD	Cabled Observation and Rescue Device
CRT	Cathode Ray Tube
CTFM	Continuous Transmission Frequency Modulated
CURV	Cable - Controlled Underwater Recovery Vehicle
CW	Continuous Wave
DS-2000	DEEPSTAR-2000
DS-4000	DEEPSTAR-4000
DSRV	DEEP SUBMERGENCE RESCUE VEHICLE
DSS	Deep Sea Survey System
DTC	Dry Transfer Compartment
ERIC	Engin de Recherche et d'Intervention a Cable (Cable Controlled Search and Intervention Vehicle)
fixed	The component cannot be moved independently of the submersible, as opposed to "trainable," where the device can be rotated or moved in either the horizontal or vertical plane
FM	Frequency Modulated
"hard" tanks	Resistant to water pressure
HF	High Frequency (3 to 30 mHz)
Hyco	International Hydrodynamics Ltd.
ID	Inside Diameter
IFP	Institute Francais du Petrole
kWh	Kilowatt-hour(s)
l.	liter(s)
LOC	Lockout Chamber
MBT	Main Ballast Tank(s)
MF	Medium Frequency (300 kHz to 3 mHz
mHz	Megahertz
MPL	Marine Physics Laboratory
man-hrs	Man-hour(s)
NA	Information not available
NAVFAC	Naval Facilities Command
NAVOCEANO	Naval Oceanographic Office
ni-cad	nickel cadmium batteries
NRL	Naval Research Laboratory
NUC	Naval Undersea Center
OD	Outside Diameter

PPI	Plan Position Indicator
p/s	Port/starboard
Pressure Hull	That portion of the submersible in which the occupants reside
RCV	Remotely Controlled Vehicle (a registered trademark)
RDF	Radio Direction Finder
RUFAS	Remote Underwater Fishery Assessment System
RUWS	Remote Underwater Work System
S^3	Surveillance System for Subsea Surveys
Sail	The portion of a submersible surrounding and protecting the hatch from flooding when on the surface
SCAT	Submersible Cable - Actuated Teleoperator
SCARAB	Submersible Craft Assisting Repair and Burial
SIO	Scripps Institute of Oceanography
SSB	Single Side Band
STP	Standard Temperature and Pressure (72 degrees F; 14.7 psi)
SUPSAL	Supervisor of Salvage
t	Tons metric (1,000kg)
TIPE	Transponder, Interrogator, Pinger and Echo Sounder
tons	Tons short (2,000 lbs)
TROV	Tethered Remotely Operated Vehicle
UHF	Ultra-High Frequency (300 mHz to 3 gHz)
UQC	*Underwater Telephone*
V	Volts
VBT	Variable Ballast Tank(s)
VHF	Very High Frequency (30 to 300 mHz)
VLF	Very Low Frequency (below 30 mHz)
w	Watt(s)

ADDENDUM[1] (15 September 1976)

The submersible DEEP VIEW, originally scheduled to complete its refitting by the spring of 1976, is not yet operational as shown in Table 2.1.

The planned refitting of DOWB has not begun.

Martech International has purchased the two completed AQUARIUS hulls. Plans are to begin completion of one hull to have an operational vehicle by the summer of 1977.

Dr. Jacques Piccard is building a new, as yet unnamed, manned submersible in Cully, Switzerland. The vehicle will accommodate three people, will weigh 10 metric tons (11 short tons) and have an operational depth of 500m (1,640 ft). It will be used primarily for research in Lac Leman (Lake of Geneva) under the auspices of Foundation pour L'Etude et la Protection de la Mer et du Lacs, Cully, Switzerland.

The operating depth of IUC's BEAVER has been changed from 2,700 feet (823m) to 2,000 feet (610m).

LEO I has been completed and is now being shipped to P&O Subsea; the maximum speed achieved was 2.2 knots (4.1 km/hr) and its payload has increased to 2,200 lbs (998kg). This vehicle may be registered as LEO III owing to previous registration of two surface ships with the same name.

Lockheed Ocean Laboratory is currently taking steps to reactivate DEEP QUEST for use by the U.S. Navy. The vehicle will be employed as a test platform for a newly developed fuel cell which is eventually aimed at powering the Navy's DSRVs.

[1]The printing of this report began on 20 September; the annual Marine Technology Society's Conference and Exhibition took place during 13-15 September. In order to include information obtained during the MTS Conference which is pertinent to this report, this addendum is included.

The Jet Propulsion Laboratory, Pasadena, California, has completed a preliminary design study of a towed device termed UDOSS (Unmanned Deep-Ocean Survey System). The UDOSS is designed to operate at depths to 6,000 meters (19,685 ft) providing bottom information for the Pacific-Arctic Branch of Marine Geology of the U.S. Geological Survey. As of this date, actual construction has not begun.

Rebikoff Underwater Products reports that a three-axis, three-propeller hovering unit is being developed for its SEA SURVEYOR system that will allow hovering in any current conditions.